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APOLLO MONTHLY PROGRESS REPORT (U)

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30 April 1962

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NORTH AMERICAN AVIATION, INC.
SPACE and INFORMATION SYSTEMS DIVISION

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FLIGHT TECHNOLOGY

APOLLO WIND TUNNEL PROGRAM

Five wind tunnel tests were completed during April. The force data now available on the command module and launch escape system (LES) cover the Mach range from 0.7 to 9.0. High Reynolds number tests of the LES in the North American Aviation (NAA) trisonic tunnel have been initiated. Model and installation details have been completed for the command module hypersonic-force tests to be conducted at the Arnold Engineering Development Center (AEDC) in July and August.

The model design has been completed for the two 0.03-scale dynamic-stability models (FD-1) to be tested in the Jet Propulsion Laboratories (JPL) hypersonic and supersonic wind tunnels. Both models will be command modules mounted in the entry position. The axis of rotation of one model will be through the off-set center of gravity. In the other model, the axis of rotation will be at the same station, but located on the model centerline. One model has been delivered to JPL for a pretest calibration.

Preliminary design studies and early test planning have been completed on the FSL-1 model. This model will provide force data from Mach 0.2 to 10.0 on the Block-II Saturn-Apollo configuration. Also included will be data on the booster after separation from the Apollo spacecraft so that information required in predicting miss distances for abort studies will be provided.

Test planning conferences have been held at Ames Research Center and at AEDC to establish model instrumentation, test dates, and data required for hypersonic pressure distributions.

Design data for the 0.08-scale SD-1 structural-dynamics model have been frozen. A test date beginning the second week of September has been established.

Test planning conferences held at Ames on the launch vehicle pressure model (PSTL-1) have established that transient-pressure testing will be conducted in the 14-ft tunnel. Static-pressure data will be obtained in the 11-ft unitary tunnel.

The status of current model and test effort is summarized in Table 1.

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Table 1. Model and Test Status, April 1962

Test Objective	Model Designation	Facility	Test Schedule	Status as of 30 April	Planned Status for 31 May
STATIC STABILITY					
Conduct preliminary aerodynamic force data and parametric study of command module shapes (JPL) Conduct launch escape subsystem configuration studies using simplified models. Mach range 0.7 to 1.5 (SAL)	FS-1 (0.02 scale) (Incl FS-7)	JPL 20 NAA-SAL	26 April to May 6 6-16 Apr 24-27 Apr	Completed basic test program in JPL. Designed and built two series of LES modifications on a crash effort basis and tested them in the SAL tunnel. Tabulated data reports published: JPL 20 in. SWT tests, and JPL 21 and 21 in. HWT tests	Publish tabulated data reports for additional SAL tests
Conduct basic aerodynamic evaluation of the design. (Ames) Determine high Reynolds number correlation data. Mach range 0.7 to 2.6 (TWT)	FS-2 (0.105 scale)	Ames 8 by 7 ft NAA-TWT Ames 11 by 11 ft Ames 8 by 7 ft NAA-NAAL	9-10 Apr 23-30 Apr 10-16 May 11-15 June 9-13 July	Ames 8 by 7 ft test of command module completed. Designed and built LES to modifications. Presently conducting tests in TWT. Started model design studies of a major modification to provide jet effects simulation by use of H_2O_2 flow through the escape motor nozzles.	Continue design and start construction of jet effects simulation. Test date indefinite (either late July in TWT or early Oct in Langley 16 ft) Publish tabulated data reports for Ames and TWT test.
Conduct same basic design evaluation of the command module and LES configurations as FS-2 tests, but extend to the Mach range of 3.0 to 10.0	FS-3 (0.045 scale)	AEDC-VKF-A AEDC-VKF-B AEDC-VKF	23 June to Jul 3 6-17 Aug 20-24 Aug	Preliminary model design studies and conferences with AEDC to establish balance and test section rigging requirements completed. AEDC personnel visited S&ID for preliminary planning conference on 2 April	Detail design and structural analysis will be completed. Construction will be approximately 30 percent complete.

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Table 1. Model and Test Status, April 1962 (Cont)

Test Objective	Model Designation	Facility	Test Schedule	Status as of 30 April	Planned Status for 31 May
Measure aerodynamic force data at hypervelocities for the entry configurations (V = 10,000 fps)	FS-4 (0.040 scale)	AEDC-VKF Hotshot II	11-29 June	Detail design and structural analysis 100 percent complete. Construction 60 percent complete. AEDC personnel visited S&ID for second test conference on 27 Mar. Pretest report SID-62-424, dated 3 April 1962, published.	Complete construction, check out model dimensions and ship to AEDC by May 25.
Determine aerodynamic force data on the complete Apollo-Saturn launch configuration. Mach range - Subsonic through M= 10.0	FSL-1 (0.02 scale)	NAA-NACAL NAA-TWT Ames - 14 by 14 ft Ames 9 by 7 ft Ames 8 by 7 ft AEDC-B and C	2-7 July 30 July 27 Aug - 7 Sept 20-24 Aug 10-14 Sept 24 Sept - 5 Oct	Design of model has been started. Preliminary planning conference held at Ames on 20 April.	Design completed, construction initiated.
DYNAMIC STABILITY					
Determine dynamic stability of the command module in the entry attitude about both the symmetric and asymmetric c-g locations. Mach range 3.26 to 9.0, using the decaying oscillation technique	FD-1 (0.03 scale)	JPL-20 in JPL-21 in	7-11 May 21-25 May	Design and construction completed; models delivered to JPL. Pretest report published.	Tests completed
Determine dynamic stability of the command module and LES Mach ranges transonic and 1.5 to 4.6, using the forced oscillation technique.	FD-2 (0.055 scale)	LRC-8 ft Transonic LRC UPWT	3-8 May 14-18 May 9-13 July 23-27 July	Monel at LRC Tabulated data report for March test at LRC published.	May tests will be completed.

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Table 1. Model and Test Status, April 1962 (Cont)

Test Objective	Model Designation	Facility	Test Schedule	Status as of 30 April	Planned Status for 31 May
STRUCTURAL DYNAMICS					
Investigate problems associated with buffeting on the SA-5 launch configuration at transonic speeds.	SD-1 (0.08 scale)	LRC-16 ft transonic dynamic	10-21 Sept	All data required from NASA-LRC for design was obtained. Design is estimated to be 40 percent complete and construction to be 10 percent complete. The indicated shipping date is now 17 Aug 1962. A design review meeting with LRC 16-ft tunnel personnel is scheduled.	Continue design to 70 percent completion and construction to 40 percent completion. Complete design, construction, and checkout of the electro-magnetic shaker assembly.
HEAT TRANSFER					
Determination of heat transfer rates for entry configuration, launch escape system, and hypersonic abort. Mach range 6.0 to 9.0	H-1 (0.02 scale)	JPL-21 in	16-25 Apr	Model thermocouple instrumentation completed and calibrated. Delivered to JPL for test 9 April. Test completed.	Tabulated data will be published.
Determination of similar objectives to H-1 tests using a larger model that permits more detailed instrumentation, better Reynold's number simulation, and addition of service module. Mach range 3.6 to 10.0.	H-2 (0.045 scale)	AEDC-VKF-B AEDC-VKF-C LRC-UPWT	18-22 June 25-29 June 20-31 Aug	Design 75-percent complete; construction 25-percent complete. Insulation and instrumentation techniques to be used represent a major refinement over methods used on H-1 model. Test planning conferences held at NAA (AEDC Tests) on 2 April and at LRC on 16 and 17 April.	Complete model design, construction, and instrumentation. Calibrate model and prepare to ship on 4 June 1962. Pretest report published.
PRESSURE DISTRIBUTION					
Determination of pressure distributions on command module in the entry and launch escape attitudes using simplified models for early loads data. Mach range 1.5 to 9.0	PS-1 (0.02 scale)	JPL 20 in. JPL 21 in.	12-16 Mar 2-14 Apr	Tests completed. Tabulated data report published for JPL 20 in. tests.	No planned model effort tabulated data report for JPL 21 in. tests will be published.

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Table 1. Model and Test Status, April 1962 (Cont)

Test Objective	Model Designation	Facility	Test Schedule	Status as of 30 April	Planned Status for 31 May
Determination of pressure distributions on the entry and hypersonic abort configurations using a larger model permitting more detailed instrumentation than PS-1, Mach range 5.7 and 10.0	PS-3 (0.045 scale)	Ames 3.5 ft hypersonic	2-13 Jul	Design 30 percent complete, construction 5 percent complete.	Complete 90 percent of design and 75 percent of construction. Pretest report published.
Determination of pressure distributions at hypervelocities on the entry and hypersonic abort configurations. (V = 10,000 fps)	PS-4 (0.040 scale)	AEDC - Hotshot II	2-20 Jul 19-30 Nov	All details of transducer instrumentation resolved with AEDC personnel. Design 100 percent complete, model structural shells complete, instrumentation in progress. Pretest report published.	Complete model instrumentation, dimensional check, and pressure test. Meet May 30 shipping date. Ship model to AEDC by 30 May.
Determination of steady state and transient pressures on the Saturn-Apollo C-1 launch configuration.	PSTL-1 (0.055 scale)	NAA-TWT Ames 14 ft Ames 11 by 11 ft Ames 9 by 7 ft Ames 8 by 7 ft	18-29 Jun 6-17 Aug 27-31 Aug 10-21 Sept 24 Sept - 5 Oct	Design 80 percent complete, and construction 50 percent complete. All instrumentation requirements resolved, and orders placed for delivery of instrumentation by approximately 15 May. Test planning conference held at Ames 18 April.	Complete construction, instrumentation, and checkout of model for TWT tests by 21 May.

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AERODYNAMICS

Force and Moment Coefficients

Component and total aerodynamic force and moment coefficients for a preliminary LES have been prepared. These data have been provided for air loads analysis; they cover the Mach range from 0.3 to 2.0 for angles of attack from 0 to 180 deg. The air loads are based on preliminary NASA test data and will be replaced when S&ID test results are available.

Force and moment coefficients for the escape rocket-plus-tower configuration have been computed for dynamic studies. The Mach range from 0.3 to 2.0 is covered for angles of attack up to 50 deg.

Work has been initiated on a computer program to integrate experimentally derived pressure distributions and to find force and moment coefficients, loading distributions, and predictions of rate derivatives.

LES Stability

Analysis of the transonic data obtained during the Ames wind tunnel tests of the 0.105-scale FS-2 model revealed a serious reduction in the static stability of the LES for a no-ballast configuration. Studies are being conducted to determine aerodynamic modifications to the configuration so that satisfactory stability characteristics may be provided with a minimum of ballast.

The relative merit of various configuration modifications must be determined by wind tunnel tests in the high-subsonic to low-supersonic Mach range (0.7 to 2.0). In order to evaluate the capability of the tunnel to duplicate force data obtained with large models, a configuration that closely approximates the FS-2 Ames model was tested at Mach 0.7 and 1.57. Good agreement with Ames data was obtained at Mach 1.57; but at Mach 0.70, a significant deviation in the measured pitching moments was obtained above a 10-deg angle of attack.

The Supersonics Aerophysics Laboratory (SAL) tunnel will be used to determine the relative merits of various configuration fixes by restricting attention to low angles of attack at Mach 0.70 and by comparing results at Mach 1.57 and above. The most promising fixes will then be tested on the large-scale FS-2 model in the trisonic tunnel; this will be followed by a detailed evaluation in the Ames unitary facility.

An experimental study of LES stability was conducted this month in the SAL tunnel. The tower length was fixed at 120 in. Configuration variables included various modifications of the escape-rocket motor nose

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and of the fairing over the exhaust nozzles. Nose modifications were intended to reduce the destabilizing contribution of the motor; the configurations included a stepped nose, a blunt-body nose, and a deflected aerodynamic surface. None of these proved desirable.

Significant improvements in stability were obtained by increasing the size of the fairing over the escape motor nozzles. Two fairing shapes were investigated: (1) 30-deg conical skirts and (2) flat discs. Various diameters were tested; results for Mach 0.68 show that an increase in skirt diameter will

1. Reduce LES drag at low angles of attack

2. Reduce pitching moment at zero angle of attack

3. Improve stability

Changing the skirt-to-rocket motor diameter ratio from 2.0 to 2.5 will increase the maximum negative moment from 0.006 to 0.0330. In addition, a disc provides greater improvement in stability than a skirt of the same diameter. These studies will be continued so that the best configurations for evaluation can be determined in the Ames unitary tunnel in May.

LUNAR LANDING MISSION

Launch Dates

Launch dates for the Apollo lunar landing mission were determined for the yr 1965 and 1966 to permit the following:

1. Launch from Cape Canaveral at least 6 hours before sunset within range-safety limits

2. Lunar landing at the Sea of Tranquility 2.5 to 3.5 days after launch, and 3.5 days after lunar dawn (45-deg lighting)

3. San Antonio approach, within the permissible entry corridor, approximately 65 hr after lunar take-off

4. Landing at San Antonio at least 3 hr before local sunset

These criteria can be met on seven launch dates in 1965 and six launch dates in 1966, beginning in June of each year and occurring at approximately one-month intervals. The most favorable launch data is 20 September 1966. This data corresponds to the near-maximum negative declination of the moon at encounter. It also coincides with the first scheduled C-5 mission for manned lunar landing.

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Service Module

Lunar Landing Analysis

Parametric data are being computed for the service module portion of the lunar landing maneuver. The basic scheme under consideration is as follows:

1. Main retro separation and service module ignition at a 450-ft-per-sec horizontal velocity and a 2000-ft altitude

2. Optimum-steering retro, ending with 10-ft-per-sec vertical-descent velocity at 1000 ft (constant thrust)

3. Constant descent at 10 ft per sec (variable thrust) while translating by tilting the body (maximum tilt angle is 30 deg from the vertical)

4. Landing flare at touchdown

This series of maneuvers is representative of the landing requirements necessary to define the characteristics of the propulsion system.

A thrust-weight (T/W) ratio trade-off has been completed for the optimum (minimum propellant) portion of the nominal flight plan. In addition, a second case for main retro staging (h = 8000 ft and V = 450 ft per sec) was considered. The resulting propellant mass ratios ($W_{fuel}/W_{initial}$) are relatively insensitive to the T/W ratio for the 2000-ft point, but they become more sensitive as the initial altitude is increased. This effect is shown in Table 2.

The propellant mass ratio required for the constant vertical-velocity descent phase, using a 30-deg tilt angle, is 0.0605. A lateral maneuver of 7650 ft can be made during this phase.

The combination of the optimum steering and constant descent-velocity portions of the landing maneuver for an initial T/W ratio of 0.6 yields a 0.1042 propellant mass ratio for the nominal flight plan. This does not include system performance, control, or manned operational control tolerances.

Optimum-Ascent Analysis

To determine the minimum characteristic velocity and propellant requirements for lunar ascent to departure orbit, a comparative analysis has been completed for direct (continuous thrust) and boost-coast-inject accent

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Table 2. Optimum Steering Maneuver

T/W Initial	$W_{fuel}/W_{initial}$
*$h_{initial}$ = 2000 ft	
0.4	0.0476
0.45	0.0470
0.5	0.0467
0.55	0.0466
0.6	0.0465
0.65	0.0466
*$h_{initial}$ = 8000 ft	
0.28	0.0669
0.30	0.0665
0.32	0.0666
0.34	0.0668
0.36	0.0673
0.38	0.0680

*For both altitudes, the other factors are identical: V_{final} = 10 ft/sec, h_{final} = 1000 ft, and $V_{initial}$ = 450 ft/sec.

trajectories to a 100,000-ft lunar-departure orbit. The analysis was based on a spherical, nonrotating moon.

Minimum propellant trajectories were determined for lunar boosts with cut-off altitudes from 25,000 to 50,000 ft, altitude-transfer coast for a half orbit to 100,000 ft, and orbit injection at that altitude.

The initial lunar-takeoff thrust-to-earth-weight ratio is 0.5 for all trajectories. Table 3 indicates the comparative results obtained.

Propellant savings of up to 500 lb can be effected for the boost-coast-inject ascent trajectory over a continuous burning ascent trajectory to 100,000 ft. Should it be desired to increase the boost burnout altitude (as shown) and/or decrease the ascent coasting range, significantly smaller propellant savings would result.

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Table 3. Comparison of Results for Lunar Take-Off, Thrust-to-Earth-Weight Ratio of 0.5

Type of Trajectory	Boost	Inject	Total
PROPELLANT MASS RATIO (V_b)			
Direct ascent to 100,000 ft	0.44389		0.44389
Direct ascent to 50,000 ft; coast to 100,000 ft	0.43510	0.001173	0.43576
Direct ascent to 25,000 ft; coast to 100,000 ft	0.43227	0.001761	0.43327
TOTAL CHARACTERISTIC VELOCITY (fps)			
Direct ascent to 100,000 ft	5945		5945
Direct ascent to 50,000 ft; coast to 100,000 ft	5787	12	5799
Direct ascent to 25,000 ft; coast to 100,000 ft	5739	18	5757

The use of the boost-coast-inject lunar-launch trajectory imposes the following added interface problems, which are currently under study: (1) An additional engine restart at orbit injection is required and must be supplied from the positive-expulsion feed system, since the characteristic velocity is small. This results in an engine-burning time of less than 1 sec. (2) An additional lunar orbit prior to transearth injection may be required, depending on launch location. (3) Overall system reliability for guidance and navigation and/or propulsion may be decreased.

Saturn C-1

Superorbital Entry Tests

The general performance characteristics that are applicable to Saturn C-1 superorbital entry tests were determined, and specific trajectories were selected for systems analyses. In all cases, velocity at the entry interface was restricted to 30,000 ft per sec. This value was based on the expected payload and launch vehicle characteristics at burnout.

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Entry trajectory characteristics varied as a result of variations in the initial path angle and manuever history. The maneuver histories considered were (1) constant bank angle, (2) constant roll rate, (3) a bank-angle change at pullout, and (4) bank-angle time history consistent with maintaining a constant altitude.

The selected maneuvers were based primarily on the ability to obtain performance comparisons, i.e., the aerodynamic heating characteristic, range and range dispersions, loads, etc. Control-system complexity would be comparable in all cases, since a three-axis attitude control prior to atmospheric entry is a tentative requirement.

Ballistic-Entry Test

Tentative suggestions based upon the results of this initial study regarding test plans for a ballistic-entry test are itemized as follows:

1. The design-load limit should be based upon a 20-g superorbital entry. This results in the attainment of stagnation heating rates approximately 20 percent below a nominal entry condition from a lunar mission. Dispersions due to extreme density variations are approximately 40 naut mi for this condition.

2. The minimum roll rate should be at least 20 deg per sec. Trajectory dispersions due to errors in roll rate increase rapidly below this value. Negligible touchdown-range variations result between roll rates of 20 and 50 deg per sec.

3. The shortest operating time for the jet-reaction system will result from initiating the rate command following aerodynamic trim ($q = 1$ psf) and then disengaging the reaction control system when the vehicle reaches the desired rate.

Lifting-Entry Test

Tentative suggestions for lifting-entry tests are as follows:

1. An active navigation and guidance system should be available before heating loads comparable to lunar entries and range dispersions within practical bounds can be achieved.

2. The desired roll maneuver during lifting-entry tests would correspond to that required for holding a constant altitude followed by an equilibrium glide. This would be consistent with control system characteristics for the operational Apollo spacecraft.

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FLIGHT DYNAMICS

Atmospheric Abort

Requirements for the launch-escape jettison motor based on computer studies of tower-separation dynamics for the command module have been established. These requirements are as follows:

1. Thrust level of 33,000 lb in the axial direction
2. Burning time of 1 sec
3. Total impulse in the axial direction of not less than 33,000 lb per sec
4. Thrust-vector alignment of 0 ± 1/2 deg in the XZ body plane and 1±1/2 deg in the XY body plane

These values provide a satisfactory tower separation for both the normal jettison mode and tower jettison after abort.

An analysis (based on a 120-in. launch-escape tower) has indicated that a thrust-vector alignment angle of 3.25 deg is required for the thrust to act through the average center-of-gravity excursion experienced during escape-motor burning. The cant angle of the exhaust nozzles has been changed to 33 deg to minimize impingement effects on the command module.

Thrust-vector control is to be provided by four hinged nozzles, each with an angular range of ±10 deg. The control concept is based on commanding the yaw and/or pitch body rates during periods of rocket thrusting. Shaping of the body rate command is currently under study.

Service Module

Maneuver requirements are being defined in order to firm the 400-lb reaction-jet propellant requirement. The current propellant system consists of two independent propellant subsystems, each containing 200 lb of propellant. Detailed studies required to substantiate the propellant system will include the following maneuver criteria for each mission:

1. Limit-cycle operation
2. Rotational transient damping
3. Angular orientations

[redacted]

4. Translational maneuvers (docking, rendezvous, service module/ command module separation)

5. Ullage maneuvers

6. Roll control during firing of the service module single-engine propulsion unit

The following design criterion has been established to define the reaction-jet thrust level of the service module: The control torque provided by the service module reaction control system A or B is to be 30 percent greater than the disturbing torque caused by full deflection of the service module propulsion system.

An analysis shows the effect of center of gravity travel on the service module reaction-jet thrust level that is required for control. The studies show that the thrust levels of 100 lb per jet are adequate but that the center-of-gravity excursion of the service module-and-command module configuration is limited to 5 in. off centerline to satisfy the control criteria.

Entry

The following guidelines are being used to assess system performance and to determine design requirements for the command modu[illegible]action control system:

1. Flying quality—trajectory control

2. Mission flexibility

3. Propellant consumption

4. System response

These guidelines are applicable for the manual mode of spacecraft control, which requires only the rate control portion of the attitude-control system, and for the attitude control loop, which requires the entire attitude control system, including guidance.

Analog computer studies were conducted in order to define the vehicle control requirements necessary for manual operation. The resulting design requirements, based on the design considerations, are defined in Table 4.

Table 4. Vehicle Control Requirements for Manual Operation

Conditions	Angular Accelerations			Angular Rate
	Roll	Pitch	Yaw	Roll
Maximum	±25 deg/sec^2			
Nominal	±12.5 deg/sec^2	±7 deg/sec^2	±7 deg/sec^2	±20 deg/sec
Minimum	±6.75 deg/sec^2	±3 deg/sec^2	±4 deg/sec^2	±10 deg/sec

The minimum value of roll angular acceleration is required for an adequate trajectory control at pullout. Response-time requirements for attitude control may be more stringent.

The design values in Table 5 were used to satisfy design requirements for the manual rate-control system.

Table 5. Values for Manual Rate-Control System Design Requirements

Conditions	Roll	Pitch	Yaw
Thrust (each motor)	100 lb	100 lb	100 lb
Motor deadband	±0.3 deg/sec	±0.5 deg/sec	±0.5 deg/sec
Rate feedback gain	1.0	1.0	1.0
Moment arms	5.7 ft (System A) 5.1 ft (System B)	5.7 and 3.9 ft	5.1 ft
Moment of inertia	3468 slug ft^2	3203 slug ft^2	3072 slug ft^2
System A angular accelerations	±9.4 deg/sec^2	+10.2 and -7.0 deg/sec^2	±9.7 deg/sec^2
System B angular accelerations	±8.4 deg/sec^2		

The 100-lb motors were chosen to satisfy roll-control requirements. The thrust levels required for adequate damping are less than 100 lb; thus, the use of identical motors is a design convenience, not a necessity.

The given deadbands are near optimum. Increasing the deadbands decreases propellant usage, but the saving is offset by an increase in the limit cycle, accompanied by an unacceptable drift in roll attitude. The fact that the unity rate feedback gains were not used is not critical.

Simulation and Evaluation

The Apollo Simulation Program Plan has been prepared. This plan integrates various system disciplines, discusses the simulation program philosopy, and includes the simulation facility requirements and schedules.

THERMODYNAMICS

Propulsion System Analysis

A new concept to integrate heat rejection from the power system and the environmental control system (ECS) into one space radiator subsystem was conceived, developed, and refined. This new subsystem provides full versatility for both lunar night and lunar day conditions, decreases weight and complexity, reduces the number of components, improves efficiency, and increases reliability. A comparison study, now under way, includes an evaluation of vendor and analytical interfaces.

A test procedure has been established to determine realistic values for the emissivity and absorptivity of candidate radiator surface coatings. Tests are scheduled to start immediately. A literature search is also being pursued to obtain further information on surface coatings and their properties.

Test facilities and equipment for the study of surface properties for space radiators have been evaluated. Additional information was obtained on new coatings and their properties.

The development of a computer program for the space radiators is continuing. An existing program was employed to study the effects of varying emissivity and absorptivity values on heat rejection and temperatures.

Optimistic surface-property values used in preliminary sizing of the space radiators indicated smaller surface areas than those required by more realistic, presently obtainable, property values. Further investigation and research is required to determine the available property values in time for the first launch requiring operational radiators. A definite mission specification would materially aid in establishing the design parameters for the space-radiator subsystems, and a computer program would be of assistance in delineating their performance.

The preliminary investigation of alternate coolants for the space radiators has been completed. Several promising coolants have been discovered. Their thermodynamic properties have been evaluated, and comparison graphs have been constructed. Further research and evaluation will be suspended until both the mission and the systems are definitely and fully delineated.

The study of the cryogenic storage subsystem has resulted in the description of some preliminary design parameters. These parameters have been disseminated to the various interested groups. The volumes, weights, and required thermodynamic states of the gases have been determined. The inside spherical diameters for the tanks have been determined for the 14-day mission. The hydrogen, oxygen, and nitrogen cryogenic storage systems were analytically optimized for the minimum residual weight consistent with a reasonable power requirement. The insulation-design requirements and the overall diameters, including insulation, will be determined in the near future.

Design parameters for the cryogenic storage heaters are being analyzed for the critical condition of a cabin puncture. This requires an integrated study of cryogenic storage in connection with the cabin-pressure control system under cabin-puncture conditions.

Aerothermodynamics

Aeroheating Analysis

During April the analysis of the thermal environment of the Apollo system was refined and extended as follows:

1. The aerodynamic heat loads imposed on the heat shield have been estimated and incorporated in the procurement specification for the heat shield.

2. The surface discontinuities and resultant local heating caused by the installation of the attitude-control jets on the command module have been studied. The severe heating rates encountered in locations above the horizontal center plane force the location of these units below that plane. Estimates have been made of the heating rates around the opening and down into the jet-exhaust nozzle to determine the local protection requirements and thermal effect on the attitude-jet system.

3. Aeroheating estimates for the launch of the escape-tower rocket motor, as well as for the combined aero and rocket-exhaust impingement heating of the escape tower and the command module, have been completed for abort conditions.

4. Heating of the service module surface, due to impingement of the attitude-control jet has been estimated.

5. A study has been made of the flows, pressures, and heat transfers in the adapter and adjacent components and structure caused by the operation of the service module rocket motor. In addition, the effect of motor spacing from the downstream bulkhead, which involves the above factors, was evaluated to determine a satisfactory design.

Wind Tunnel Program

The heat transfer tests were completed on a thin-skin model, at Mach 6.0, 7.3, and 9.5 under launch and entry conditions in JPL's 21-inch tunnel.

A preliminary evaluation indicates that satisfactory data have been obtained for the conditions of the test. The performance of the tunnel, the model, and the data acquisition system was very good. An attempt was made to study the effect of turbulent versus laminar flow on blunt-face heat transfer during entry by installing a boundary layer trip. The success of the attempt will be evaluated when the final data are received.

Environmental Control Systems Analysis

Document Revisions

A revised work statement now reflects the latest requirements and reference specifications, and design criteria are now compatible with the Apollo design criteria specification. The system schematic was revised to provide a maximum capability for heating and cooling the cabin. The airlock valving was revised to allow two or more crew members to perform extravehicular operations simultaneously and to allow area control of the space radiator to prevent coolant freezing.

Suit Circuit

There are three major changes to the suit circuit. The demand regulator was moved downstream of the crew to prevent a sudden drop of pressure when a crew member opens a face plate. The suit manifold now has a pressure-controlled bypass to prevent variable flow to other crew members should one crew member increase or decrease flow. The manifold also includes a venturi in each suit-inlet connection to prevent a loss of suit flow to other crew members if the suit of one crew member should rupture. In this situation, venturi prevents the damaged suit flow-out from exceeding the maximum flow of demand regulators. The circuit water evaporator and coolant loop heat exchanger of the suit have been integrated into one through fluid exchange. This was done because of space-envelope problems. It also provides for a coolant-temperature control for subsolar operation on the moon.

Coolant Loop Circuit

The coolant loop was revised from a three-parallel-path system to a temperature-cascaded system. In general, valving has been provided to accomplish the desired results. For a cabin-cooling mode, the suit heat exchanger, cabin heat exchanger, and electronics heat exchangers are in series and in that order. For a cabin-heating mode, the suit exchanger, electronics heat exchangers (cold plates), and cabin exchanger are in that order. During a heat mode, the heat that is dissipated by the electronics is rejected to the compartment.

Space Radiator

The space-radiator plumbing arrangement has been revised to provide for area selection. With area selection, the desired coolant temperature can be achieved for a wide variety of heat loads and operating conditions. This system revision was discussed in detail with NASA representatives.

Studies

The major studies on which progress has been made during April include utilization of the back-pack life support systems for in-cabin suit operation, catalytic filter requirements, and environmental capabilities during lunar night operations. The status and results of these studies are as follows:

1. Results of back-pack life support system utilization study indicate that, by using the back packs for emergency cabin decompression and for re-entry, some components of the suit circuit can be eliminated and the suit circuit power requirements can be reduced. Completion of this study is pending NASA's selection of a back-pack contractor, so that interface problems can be determined.

2. The objectives of another study are to determine the effect of leakage from both the compartment and suits on catalytic-filter

operation, the by-products formed by catalytic action for various gases and catalytic materials, and gas-flow rates.

3. A study of environmental control system (ECS) heating capabilities for lunar night operations is complete. This study indicates that because of the low electrical heat loads and relatively low temperature (70 to 100 F) required to cool this load, the ECS system is not capable of providing sufficient heating. A preliminary study of possible supplemental heat sources indicates that the integration of the ECS and fuel-cell coolant system is the most promising. The results which have been obtained from this study thus far were presented at NASA's design-review briefing.

A study has been initiated to determine the shielding effectiveness of the Apollo command and service modules. One purpose of this study is to determine how effective the Apollo vehicle weight will be in stopping the proton radiation resulting from solar-flare events. This study seeks also to determine how much additional water-shield weight will be required to attenuate incident-proton radiation to safe body-dose levels.

The first part of the study, already completed, consisted of segmenting the Apollo command and service module into six solid angles, each angle representing a different shielding-weight effectiveness. Figure 1 shows the weight distribution for the command and service modules as a function of the total module surface area. Table 6 tabulates the water-equivalent stopping power for the six solid angles.

Table 6. Water-Equivalent Stopping Power

Region	Area (sq ft)	Total Weight (lb)	Thickness (lb per sq ft)	Water Equivalent For Areas	Water Equivalent (gm per sq cm)
A	43	14,700	340	1:1	166
B	120	27,136	226	1.2:1	92
C	15	239	15.9	1.5:1	5.2
D	135	2,354	17.4	1.5:1	5.7
E	29	204	7	1.6:1	2.1
F	53	1,217	23	1.5:1	7.5

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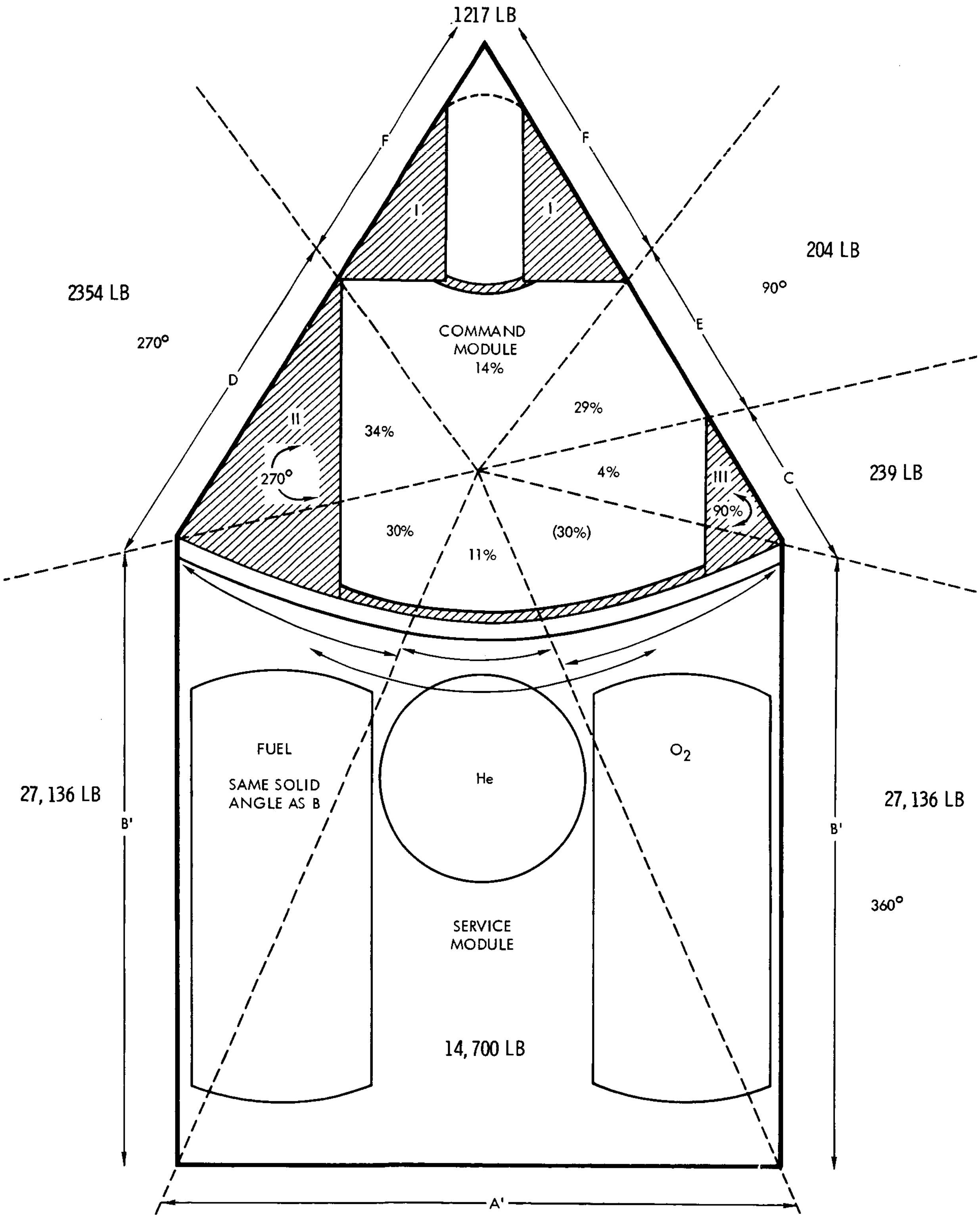

Figure 1. Weight Distribution as a Function of Total Surface Area

The next phase of this study will involve calculating the body-dose levels resulting from solar-flare proton radiation. The purpose of this study will be to determine the body-dose radiation expected as a function of solar flares encountered number and size, mission length, and water-shield weight.

Tests

Tests of personnel in pressure suits at various work loads will start next month. The test plan was presented to NASA representatives at an informal meeting. The object of the test is to determine realistic, sensible, and latent heat loads during suit operations. The start date depends primarily on the delivery of a Mercury suit by NASA.

Thermodynamics test parameters are being determined for ECS breadboard systems test at S&ID and for the space-simulator (thermal-vacuum) test on the actual vehicle. Preliminary data have been completed for facilities development.

Water Management

A water-management analysis has been completed. This analysis was based on the latest electronic equipment cooling requirements, thermal loads through the cabin walls, and the use of deployable space radiators. Results indicate that not all water generated by the fuel cells will be required and that some may be dumped to decrease lunar-landing and lunar take-off weight.

A series of preliminary design studies is being made to establish equipment-cooling system concepts and the design criteria for boilerplate vehicles. To date, studies indicate that ground cooling will be required for boilerplate 6 (pad abort) when the desert conditions specified by MIL-SID-201A are used. The ground-cooling requirements appear to be excessive for these climatic conditions. Therefore, an investigation is being made to determine a realistic climatic condition at the launch sites for the presently scheduled launch dates.

For ground operation, cooling requirements for boilerplates 12, 20, and 21 would be similar to boilerplate 6.

The IBM 7090 computer is being utilized to determine (1) the flow pattern that will give the most uniform temperature distribution, (2) cold-plate surface temperatures when experimental values of contact resistances are used, (3) flow rates for set cold-plate temperatures, and (4) effects within the cold plate when uniform heat flux is applied.

To date, one plate has been analyzed for temperature distribution. The cold-plate surface was loaded uniformly at 2.5 w per sq in. and the coolant flow rate was 48 lb per hr. The temperature profile was satisfactory, but temperature levels were higher than the anticipated heat flux.

A test program was initiated to evaluate materials for reducing the thermal resistance of the contact surface between the electronic equipment and the cold-plate heat sink. A test setup was completed, and shakedown tests were run. Dry aluminum surfaces having finishes of approximately 60 rms micro-in. produced a sea-level condition conductance of 90 Btu per hr per sq ft per deg F, which was lower than that assumed in the analysis. This indicates that such surfaces are inadequate and that a lower resistance must be attained. S&ID is searching for suitable materials to test. Thermal properties for both sea-level and space-vacuum conditions are to be obtained for all materials tested.

In-Flight Nuclear Radiation Instrumentation (Preliminary)

A solar-flare warning system would provide 8 to 10 min warning before the arrival of solar-flare proton radiation. This would be a dual system. One alarm signal would be an on-board system to detect solar X-ray or ultraviolet radiation. The second alarm system would be a ground visual system for telemetering solar-flare warning signals to the Apollo command module. Both of these warning systems would permit the crew to take protective action before the arrival of solar-flare proton radiation.

Rate or Integrated Dose Measurements

This readout system would provide individual body-dose readings; this would permit a crewman to average the total dose of radiation received throughout a lunar mission.

Radiation Analyzer

This system would allow a crewman to determine the internal nuclear radiation environments at four locations within the command module and would present the type and intensity of secondary radiation existing within the module.

Thermal Analysis

Command Module Attitude-Control Rockets

A preliminary thermal study indicated that severe overheating during re-entry of the command module attitude-control rockets could be expected when the rockets are located 45 deg from the stagnation point. As a result of this analysis, the rockets have been relocated to positions that are more favorable from a thermal-environment standpoint. In the new locations, the nearest angular distance of an attitude-control rocket to the stagnation point is 92 deg. The maximum, expected, nonoperational rocket nozzle temperature is now 2710 F (the upper allowable limit is 2800 F).

Command Module Parachute Compartment

An analysis of the thermal environment in the command module parachute compartment has shown that for nonoperational conditions the temperature extremes can be as high as 250 F and as low as -200 F. The operational environment just prior to and during re-entry, which depends on vehicle orientation during the return to earth from the moon, can be as high as 200 F and as low as -155 F. This information has been transmitted to the parachute subcontractor.

Launch Escape System

The truss support for the LES must be able to maintain structural integrity within all of the thermal environments imposed by aerodynamic heating during boost and by the heating from the escape-rocket plume during abort or tower jettison. The weight of the ablative material required to adequately protect the truss to a given maximum temperature was approximated by using data derived from the following simplified conditions: (1) The aerodynamic heating rates are based upon a concept in which the flow is considered normal to the surface of a tube and in which the stagnation temperature is assumed to be constant about the tube circumference. (2) The escape-rocket plume is assumed to impinge upon the entire structure. (3) The ablation heat and temperature of the materials are assumed to be constant and are taken as the average values.

The thickness of two ablative materials as a function of maximum permissible tube temperature is shown in Figure 2 for a tube diameter of 3.3 in.

Antenna Windows

A tentative design for the C-band antenna window is shown in Figure 3. The window is designed to withstand a surface temperature of 3200 F and maintain the back-face temperature below 200 F. The approximate temperature distribution at the end of re-entry for a maximum overshoot trajectory and a maximum undershoot trajectory is given in Table 7.

The beryllium heat sink shown in Figure 3 was not considered in these calculations. This indicates the need for a heat-sink material around the bubble-alumina legs.

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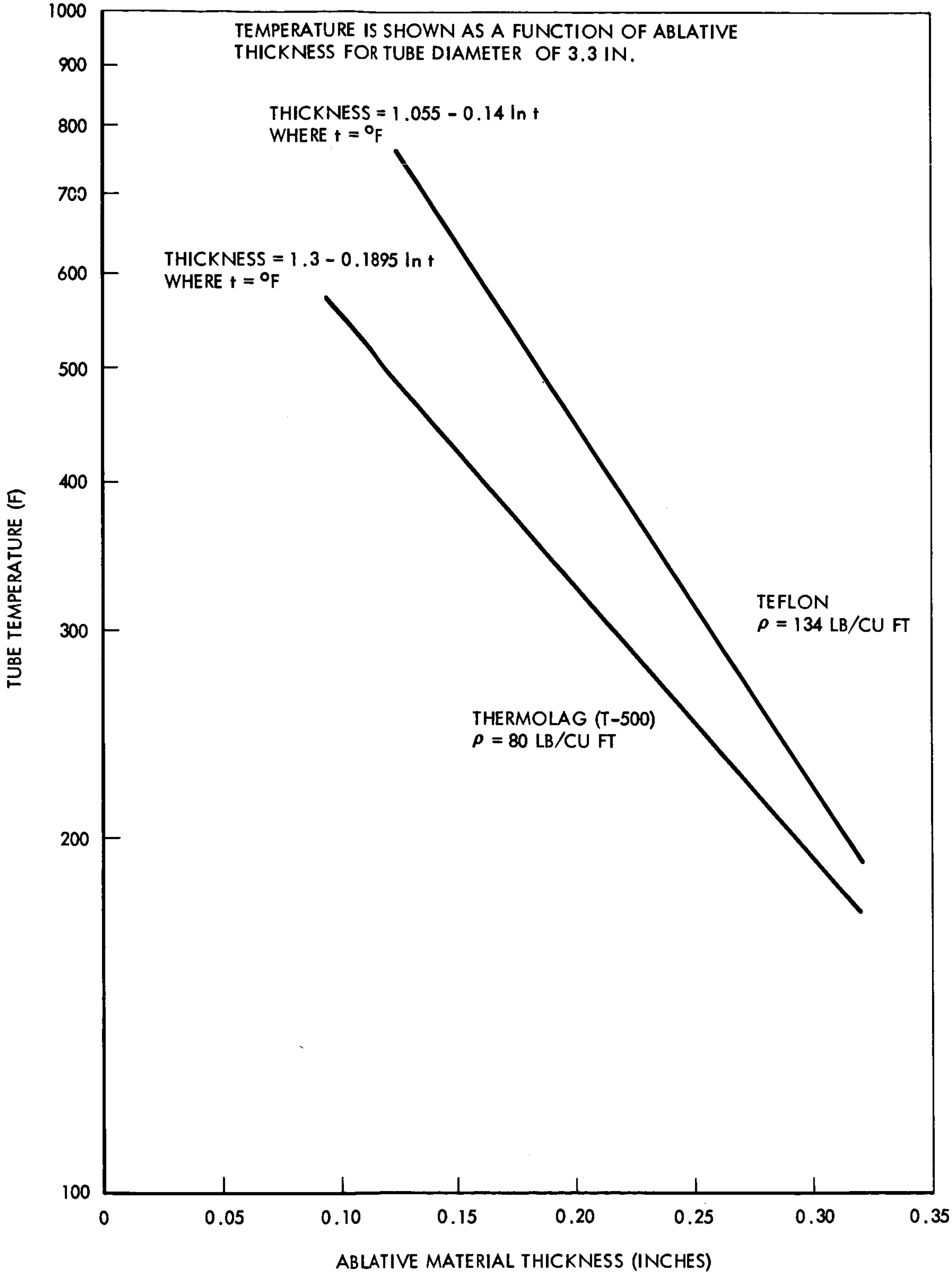

Figure 2. Escape Tower Truss Member Maximum Permissable Temperature

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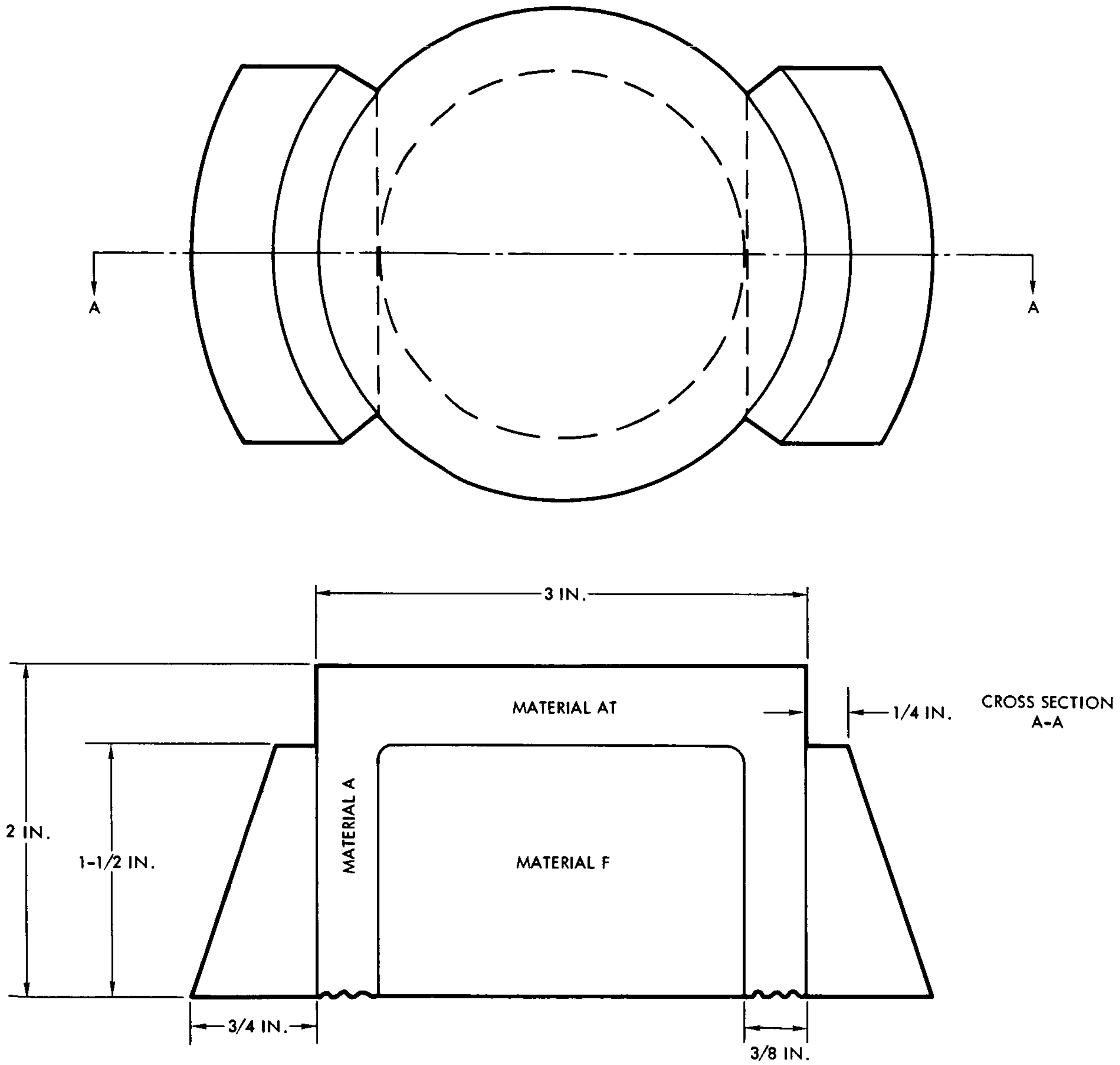

MATERIAL A: BUBBLE ALUMINA
MATERIAL AT: BUBBLE ALUMINA IMPREGNATED WITH TEFLON POWDER
MATERIAL F: FORMED FUSED SILICA (GLASROCK)
ALUMINUM PHOSPHATE BOND
SAUEREISEN P-1 PORCELAIN BOND

Figure 3. C-Band Antenna Window

Table 7. Appropriate Temperature Distribution at End of Reentry

Distance From Front Surface (in.)	Max Overshoot Trajectory		Max Undershoot Trajectory	
	End (F)	Max (F)	End (F)	Max (F)
0.0		2500		3000
0.5	1200	1800	2100	2100
2.0 Material "A"	1000	1000		
2.0 Material "F"	140	140	100	100

Backup materials for the C-band-antenna window are multiform silica, dense-coated fused silica, foam (Glasrock), and Duriod 5650. A computer program is now being written for the design shown in Figure 3. This can be modified to include the backup materials.

Ablation Heat Transfer Studies

Programing of the thermal protection system analysis is progressing. A method has been chosen for predicting temperature distribution in the heat shield prior to ablation, and a subroutine has been written and compiled. This solution is general and is applicable to transient thermal analysis problems. A sample case for checkout out the method is being prepared.

The equations used to predict heat balance during ablation were written for a two-zone model of a charring ablator. The first zone concerns the energy balance of the uniformly porous char while the gaseous decomposition products flow through. The second zone consists of the unaffected plastic coupled with honeycomb and other substructure. The continuity of heat flow for the assumption that the decomposition is isothermal permits the solution of these coupled equations. It is still desired to consider the reaction more completely by dropping the isothermal assumption and expressing the reaction as temperature-rate dependent. However, until the physiochemical parameters are established from experiment, this refinement will be delayed.

Test Program

A test program, which will determine the feasibility of instrumentation and sampling techniques, has been designed for analysis of thermo-chemical reactions. A test program has been designed to investigate chemical reactions during ablation. Manufacturing of honeycomb-sandwich panels for measuring thermal properties has been approved. Computations have been made on the amount of power needed to perform a thermal stress test on the entire Apollo command module.

An ablation test model is being designed for testing in a re-entry simulation facility. The objective is to obtain the coefficients that represent the thermal, chemical, and structural properties of a charring ablator during the ablation process. These properties will then be used to predict the behavior of the ablative material during hypersonic environmental conditions.

The theoretical model adopted for the ablation analysis considers three distinct interaction zones (as developed by Scala and Gilbert): the char layer, the reaction zone, and the solid virgin material. The theoretical equations describing thermal degradation of the ablative material in these zones will be utilized to reduce the experimental data obtained from ablation tests. These equations have been verified analytically, and it is believed that accurate measurements of the desired properties will be obtained.

Initial design efforts have been directed towards determining the size, location, and the number of thermocouples required on the basis of theoretical temperature distribution in the ablating material. In addition, a thermocouple error analysis is being performed.

Propulsion Systems Analysis

A pressurization system analysis (by approximate methods) is in progress. Pressure drop in the pressurization system, tank-pressure relief valve flow required, helium bottle size required, and weight and reliability trade-off for adding heat to the pressurizing gas have been accomplished by approximate methods and a more detailed analysis is in progress.

An analysis was made of pressure relief valve geometry requirements to safeguard the propellant tanks for a multiple full, open flow regulator failure. A cumulative effective flow area of 5.5 sq in. was found to be necessary. The analysis was based on the premise that no propellant exists in the pressure relief line when this failure mode occurs.

~~CONFIDENTIAL~~

A mathematical model was formulated to describe the relationship of the helium pressurization supply reservoir concerning ullage conditions. It is planned to program this system of thermostatic equations for a parametric-numerical solution by the IBM 7090 computer. This study will aid in optimizing the helium reservoir volume, the flow-regulator orifice areas, the check-valve minimum areas, and similar data required for GSE.

Parameter pressure loss data was obtained for helium flow devices undergoing a one-dimensional, compressible, sudden-expansion process. The analysis is based upon adiabatic, constant-momentum, and constant-energy conditions.

Generalized data have been developed to enable the determination of the tank ullage required for various conditions of temperature and pressure.

Partially completed is an investigation of the ullage volumes and pressures that will be required in the propellant storage tanks of the service module main propulsion system at conditions of lunar touchdown. Owing to present uncertainties in the areas of initial fill conditions, temperature at lunar touchdown, and details in tank design, definitive conclusions cannot be reached at this date. However, early indications suggest that if the oxidizer storage tank is designed for an initial ullage volume in the range of 15 to 30 percent and fill temperatures in the range of 60 to 100 F, the ullage volume at lunar touchdown will be about 100 psia maximum. This corresponds to a ullage volume at lunar touchdown of 15 to 25 cu ft (5 to 12 percent).

Pressure-drop calculations were completed for the propellant flow systems of the command and service module reaction control systems and for the service module main propulsion system.

Gimbaling methods for the service module main propulsion motor were defined and studied in support of the pending procurement specification release for gimbal-actuator systems.

A preliminary analysis of temperature extremes in the service module has been completed. The following recommended design temperature limits for the propellant systems are based on this analysis:

Location	Maximum Temp (F)	Minimum Temp (F)
Service propulsion system tanks	104	44
Components remotely located from SPS tanks	160	-40*

*Components containing propellants will require heating to maintain a minimum temperature of 35 deg F.

~~CONFIDENTIAL~~

The effect of zero gravity or low gravity level environment of Apollo propellants is being studied. A literature survey has been partially completed; problems of propellant location in the tanks, tank ventings, and propellant sloshing resulting from altitude-control transients during zero conditions are being considered. Possible solutions to these problems are being formulated for consideration.

Rocket Engine Systems

A survey of regeneratively cooled and ablative engines was conducted in support of the service propulsion evaluation. It was concluded that the regeneratively cooled thrust-chamber development is in a more advanced stage than the ablative. However, the fuel freezing problem will tend to rule out regenerative cooling unless a different (low freezing) fuel is selected or an engine purging or heating system is added.

An analysis of a proposed, regeneratively cooled, service module rocket engine showed that the performance of the cooling system is marginal and that thrust-chamber film cooling is necessary.

A comparative development and cost analysis was prepared of variable versus constant-thrust 20k rocket engines using storable propellants.

The bleed-expellant investigation indicated that coolant weights for full expansion ($A/A^* = 40$) would be excessive. Relocation of the reaction control system (RCS) rockets to a cooler location appears to be the better solution. However, there is evidence that cooling may still be necessary in the new locations. At present, a thermal study is being pursued to determine the temperature of the stagnant fuel in the cooling coil as a function of re-entry heating. A preliminary analysis is presently under way.

Interface Systems

Simplified methods have been set up for predicting properties of the exhaust plume in a vacuum and in the atmosphere. The exhaust plume impingement pattern was established for the idealized service module reaction control, and the heating effects were calculated.

A preliminary analysis of the plume heating of the command module by the LES (19-deg-cant angle) indicated a high heating rate. Summation reports are in progress. Research for better methods of predicting the plume profile and the impingement patterns is continuing. Service module S-IV interface problems have been considered. Results indicate that a test program should be devised for determining the separation distance.

A report in progress covers the use of solid rockets for separating the service module from the S-IV instrument wafer in the abort situation that would occur after jettisoning the LES.

GSE Support

A sizing analysis of the propellant tank fill and vent has been completed. This was a parametric study, covering the command module, reaction control system, service module, and RCS service propulsion system and comparing the various line sizes with the fill time and fill pressure required. Future studies will include a propellant delivery, temperature-optimization analysis and an analysis of propellant-boiloff losses in transfer lines and spacecraft tankage.

An analysis that evaluates the boiloff losses to be anticipated in a liquid hydrogen fill system has been completed. The losses include boiloff from the GSE tankage, transfer line cooldown losses, and heatleak losses after cryogenic temperature stabilization.

An evaluation of the GSE test procedures and requirements has been initiated for items associated with propellant, cryogenic, and gaseous fill systems.

PLANNED ACTIVITIES

Heat transfer rates in the 5.0 to 9.5 Mach number range will be measured (with the H-1 model in JPL's hypersonic wind tunnel) on the command, service, and command-service modules.

INTEGRATION AND SYSTEMS ANALYSIS

CONFIGURATION CONTROL

Studies to determine boilerplate hardware requirements on an overall program basis have been completed, and a preliminary hardware list for each boilerplate is being compiled. Boilerplate 1 is being given principal attention.

General configuration arrangements for the boilerplate test vehicles and spacecraft vehicles have been prepared. A rough draft copy of the document presenting the methods to be utilized in determining and controlling the configuration of the GSE has been prepared. A single document containing all the necessary requirements for serialization, traceability, and material control will be prepared and will include all the information now contained in a myriad of customer and contractor reports and specifications. Subcontractor and contractor configuration and change-control documents have been prepared, and a preliminary inboard profile layout has been completed.

LOGISTICS

The preliminary maintenance analysis of the first Little Joe II-launched spacecraft has been completed. Data are being compiled for internal support planning and are scheduled for inclusion in the first revision to the maintenance plan.

The requirements for the support of initial boilerplate testing at S&ID have been reviewed for support parts determination. GSE requirements in support boilerplate 1 have been released for manufacturing to the extent that the final design has been determined.

SYSTEM REQUIREMENTS

A revised specification tree was prepared and presented to NASA for concurrence. The specification for boilerplate 1 was revised.

The first revision to the technical development plan includes an expansion of the major system development area. System development logic networks were prepared.

Revised definitions and objectives for mock-ups, boilerplates, and spacecraft were made on the basis of verbal communications with NASA.

Preliminary development program schedules were prepared for the lunar excursion module and the two-stage service module "B" configuration.

Revision of the spacecraft performance and design criteria specifications is in process.

An analysis has begun of the Apollo launch operations, functions, and information flow.

The logic network is being prepared for both normal and contingency operations. Revised mission timeline charts have been prepared for four typical missions. These include the major events, operations, and functions for each mission mode. The next edition of these charts will include flight parameters, such as altitude, velocity, earth-trace position, g-loading, and GOSS activities.

SYSTEM INTEGRATION

S&ID design groups and NASA made a compilation of instrumentation lists and schedules for abort-test boilerplates 5, 12, 20, 21, and 23.

A study relating to the checkout interface among GSE, in-flight test, and telecommunications was completed. This concept is scheduled for presentation to the design review board early in May.

The checkout criteria specification has been revised to include inputs from various groups.

A plan for the design of electronic modules and cable routings was prepared to provide maximum electromagnetic interference control while optimizing weight, space, and volume requirements.

A report was issued on the subject of electromagnetic interference from fluorescent lamps and brightness controls.

Discussion at systems integration coordination meetings resulted in the design of a new reaction-jet configuration for minimizing heating problems during earth entry.

TEST INTEGRATION

A revised format has been established for the development test plan outlined in SID 62-109. Additional inputs from the design groups have been incorporated into sections that pertain to an overall concept and to development tests of individual systems. The appendix sections, which include considerable detail of the respective systems tests, are being revised.

MATERIALS AND PRODUCIBILITY

Launch Escape Tower Analysis

A producibility study of the launch escape tower structural skirt as a forged, machined, and welded design has been initiated.

Command Module Analysis

A specimen of the Stresskin, all-welded, PH 15-7 Mo honeycomb sandwich with face sheets chemically milled after sandwich assembly was obtained from the Chemical Contour Corporation. This method appears to be a logical means of solving problems caused by the unavailability of thin-face sheets in dimensions required for the production of large, light-weight, Stresskin panels. The chemical milling of assembled Stresskin panel skins may result in near-optimum strength-density ratios.

Development of a standard thermal shock test for the honeycomb sandwich panel evaluation was started. This procedure will be evaluated and developed with PH 15-7 Mo panels and used for other honeycomb-sandwich types.

A program to show how holes of varying sizes in the charring ablator will affect the metal-honeycomb substrate has been started.

A literature survey is being conducted to determine the availability of data on the performance of transparent thermoplastics (e.g., acrylics and polycarbonates) under such space environments as hard vacuum and radiation. Transparent thermoplastics are being considered as meteoroid protective covers on the command module windows.

An investigation is being conducted to evaluate problems involved in the assembly of the silicone-rubber, thermal insulation joints of the room-temperature vulcanizer between the command module inner shell and the heat shield structure. A full-length typical joint is being built; and assembly problems will be studied for the precured rubber, the wet rubber assembly, and the rubber injection techniques (if required).

Tooling is now available for the production of a curved, diffusion-bonded, honeycomb panel. This curved panel should be completed and delivered in two weeks. A two-week test program is being conducted to evaluate the amount of probable sandwich skin warpage resulting from the skins being welded to the adjoining structural framework prior to bonding. Explosive sizing will be tried as a possible means of correcting such warpage.

Several methods have been considered for the production of large aluminum rings to be used for load-carrying members in the command module. Flash and fusion butt welding of the plate were considered possibilities, but the most promising method of producing these rings appears to be hot die forging.

A detailed plan for the hard-vacuum testing of adhesives for bonded aluminum honeycomb has been completed. Some preliminary lap-shear specimens are currently being exposed to a 10^{-9} vacuum in a 14-day test.

Service Module Analysis

A study of the properties of closely controlled titanium-alloy compositions for the helium tank was initiated this month. Preliminary weight comparisons indicate that an A-110 titanium-alloy tank would be slightly lighter than the 2024 aluminum-alloy tank. However, developmental work will be done considering future tank configurations.

An evaluation of forging versus shear-spinning as alternate forming methods for the pressure-vessel domes is near completion. The results indicate that forging is the better method.

A producibility and structural-test section of the service module radiator is being fabricated.

Work has started on methods of joining liquid and gas service lines by means of brazing and welding.

A producibility and material study is being made on the rocket engine to compare the ablative chamber design with the liquid-cooled chamber design. Although ablative chambers have been successful on smaller engines, there is no service history for one used in an engine of this size.

Drop forging has been selected as a forming method for producing the large hemisphere required for the helium tanks. It has also been concluded that the welding of these vessels must be done in a chamber to ensure high-ductility welds. This type of welding can be done in an inert gas atmosphere using the tungsten inert gas (TIG) welding process or in a vacuum using the electron-beam welding process. Considerable data are available from the proof-testing vessels that were welded with the TIG process in an inert atmosphere. There may be some advantage to welding these with the electron-beam process, but there are no test data available.

SUBCONTRACTOR RELATIONS

Procurement arrangements for the 6Al-4V structural-tube specimens were initiated. The minimum thickness of the 6Al-4V sections to be fusion-welded is 0.050 in.

Command Module

Sources and methods are being investigated for producing large, heavy, 2014 aluminum rings (for the inner shell of the command module) that have acceptable and reliable welding properties.

Service Module

The purchasing department has been requested to obtain a bid from Airite Products for the fabrication of several helium tanks made by the electron-beam welding process with the vendor's production hemispheres.

PLANNED ACTIVITIES

A test program will be planned to determine the effects of hard vacuum on lubricants over long periods of time.

An investigation is being made of the state of the art and the availability of suitable umbilical and pressure-tight connectors for the Apollo spacecraft. A listing of measured events for checkout is being compiled.

A design-disclosure package was prepared for stage 2 of the "B" service module in accordance with NASA's request. A similar package for stage 1 will be prepared by 3 May.

Studies are also being conducted on configurations that would be compatible with the lunar-excursion module and that would utilize the full 80,000-lb injected-payload capability of the C-5.

A large (16- by 36-in.), flat, diffusion-bonded, titanium honeycomb panel will be tested so that the value of this method of fabrication for the command module and the advisability of further investigation in this field can be determined.

A study is being conducted to further substantiate the metallurgical requirements of the inner shell and to control these requirements by a nondestructive testing method.

A project is being planned to determine the best production method for fabricating the service module radiators. Under consideration are the dip-braze method of attaching tubing to aluminum skins and the expanded integrally tubed skin method (per refrigeration practices).

A test program in which pressure vessels will be welded by the electron-beam process has been drafted. These will be compared with conventionally TIG-welded specimens.

Maintenance analysis of subsequent spacecraft and associated GSE is in progress. Review of the requirements for support of boilerplate testing will continue in order to provide support parts determination.

RELIABILITY

The revised issue of the Reliability Program Plan (SID 62-203) was transmitted to NASA. An appendix containing deviations in the requirements of applicable documents has been prepared and will be included in the report.

Descriptions of qualification and reliability tests were prepared for inclusion in the revised issue of the Test Plan (SID 62-109). Reliability test requirements for the environmental proof spacecraft were included.

RELIABILITY STUDIES

A reliability study of explosive bridge wire versus hot wire pyrotechnic ignition was performed. The results revealed that either system, when properly designed, meets reliability and safety requirements.

Reliability evaluations of three proposed command-to-service-module separation systems have been completed. The most desirable system which is energized by a single gas generator ignited by dual squibs, provides the working medium for three actuators. The actuators disengage structural pressure points by means of a mechanical toggle linkage.

ENVIRONMENTAL CRITERIA

Environments anticipated during transportation and storage of spacecraft and associate GSE were defined.

ENVIRONMENTAL CONTROL SUBSYSTEM

An S&ID/NASA meeting on the environmental control subsystem was held during the report period. Past experience from Project Mercury revealed that check valves created a significant problem with their tendency to fall shut. NASA recommended that the entire command module, as well as the affected subsystem, be checked out in a vacuum chamber. NASA personnel are to forward to S&ID the following Mercury information:

1. The AiResearch reliability test program
2. Environmental control subsystem failure data
3. Cold-plate configuration and temperature profiles
4. MA-6 flight plan and voice tape

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NAVIGATION AND GUIDANCE SUBSYSTEM

NASA called a meeting at S&ID concerning the problem of reliability apportionment to the navigation and guidance subsystem. The problem arises from the MIT employment of Mark II Polaris guidance elements, along with other required equipment, that will not permit achievement of the assigned objectives, even with alternate modes of operation in the event of a failure. The MIT reliability goal could be met with on-board maintenance and spares and with a standby inertial measuring unit (IMU—60-lb and 14-in. spherical volume). This statement was later found to be applicable only to that phase of the mission which culminates in a lunar landing.

Continued study and improved liaison between NASA, MIT, and S&ID are required on these subjects if a practical solution is to be gained. NASA requested that S&ID conduct studies of the following:

1. Ramifications of reducing mission success requirements, while maintaining the current level of crew survival probability

2. Landing paths under various contingencies ranging from accurate, fully functioning guidance landings to the worst case conditions within crew survival limits

A preliminary maintenance support policy and plan has been generated with the object of sustaining mission phase reliability and have safety requirements for the command module, service module, and ground complex.

SUBCONTRACTOR RELATIONS

Qualification-reliability test procedures are being prepared for the helium tank specification and for the supercritical gas storage system. These procedures include the requirements for environmental tests and the methods of test result analysis to be followed by the supplier to determine whether qualification and reliability criteria have been met.

At a meeting held with AiResearch personnel, a request was made that the next revision of the AiResearch Reliability Program Plan contain a discussion of Mercury experience and of the methods to be followed to preclude similar problems on Apollo.

PLANNED ACTIVITIES

Work is continuing on the development of a reliability training program. A preliminary curriculum of 13 subjects has been established for early course implementation, and course outlines are being developed for these subjects. "Computer Methods of Circuit Analysis," the first Apollo Reliability training course, began on 17 April.

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INSTRUMENTATION

CONTROLS AND DISPLAYS

Study, analysis, and coordination of requirements were continued for controls and displays, for the in-flight test system, for packaging for electronic systems, and for electromagnetic-interference testing. Detail requirements for many of the controls and displays have been gathered and furnished to the life systems group. Backup-entry display studies are continuing; the goal of these studies is simplification of the necessary equipment. A drawing that defines the volume of the main instrument panel was prepared.

Displays and controls were obtained for demonstrating the co-planar portion of the rendezvous maneuver.

POWER REQUIREMENTS

Electronic system power requirements were prepared for design review. Documentation was prepared for the design data manual, Apollo test plan, hardware list, drawing list, design criteria specification, and system performance specifications.

INTEGRATED OPTICAL DISPLAY

A study of an integrated optical display has resulted in drawings, block diagrams, a description of the functions, and tentative solutions to problem areas. This work is being reviewed, and trade-offs are being made to define the concept.

LOWER EQUIPMENT BAY CONCEPT

The lower equipment bay standard electronic module concept was formulated. A space assignment and outline drawing will be available next month. Work has begun on the design of fasteners, cold plates for cooling the electronic equipment, and wiring-harness channels.

IN-FLIGHT TEST SYSTEM

A preliminary concept of the in-flight test system has been coordinated with the affected subcontractors so that an integrated definition of test-point characteristics can be formulated.

Based on the preliminary concept reported last month, a weight-and-volume review was started for the in-flight test system.

A simulated crew readout was obtained for delineating the output reading of the in-flight test system.

After being compared with alternative approaches, a specific packaging design of semihard mock-up 1 was prepared for formal review.

MEASUREMENT SYSTEMS

An overall approach to a central timing system for the Apollo spacecraft has been established. A report outlining the present S&ID concept and status of compiled clock requirements has been prepared.

General system design considerations for employment of a signal-conditioner are being compiled. Included in this investigation are patch-panel and calibration considerations.

R & D INSTRUMENTATION

Instrumentation requirements for the pad-abort test spacecraft (boilerplates 6 and 20) and the Little Joe II, max q spacecraft (boilerplates 12, 21, and 23) have been established, and specific equipment requirements are presently being determined.

PLANNED ACTIVITIES

An evaluation of transducers applicable to the operational instrumentation requirement will be started.

Installation design on the NASA-furnished R & D instrumentation systems for the pad-abort test spacecraft and the Little Joe II, max q spacecraft will be started.

An analysis to establish the S&ID/NASA instrumentation requirements for SA-5 and SA-6 will be conducted.

SIMULATION AND TRAINING

TRAINING EQUIPMENT

The following reports were submitted to NASA for review and comment: Training Equipment Requirements (SID 62-358) and Mathematical Outlines for Design of Crew-Training Equipment (SID 62-387).

Trainer perspective drawings were included in SID 62-358.

Twenty training-equipment performance specifications (SID reports 62-496 through SID 62-515) have been completed.

TRAINING PLAN

The preliminary Apollo Training Plan (SID 62-162) has been approved by NASA. Work is currently under way to delineate training for the Apollo flight crew, flight operations, and preflight operations personnel. Estimates of the personnel who must be trained and the training, training devices, instructor personnel, facilities, and documentation that will be required are now available.

Coordination with Minneapolis-Honeywell, Collins Radio, and AiResearch has been initiated so that their input to Apollo training can be integrated with the S&ID material.

PLANNED ACTIVITIES

The training-equipment performance specification will be revised according to NASA comments and recommendations.

A design study of visual simulation techniques for the crew part-task trainer and flight trainers will be completed.

Preparation of the procurement specifications for major training equipment components will be initiated.

The main effort by Logistics training during May will be the preparation of the training plan revision due for publication 31 May 1962. This revision will include the following:

1. A synopsis of spacecraft training requirements for flight crew, flight operations, and preflight operations personnel

2. Suggested assignments of responsibility for training and training support requirements

3. Facilities required for the training program

4. Time phasing of training based on availability of systems, information, training equipment, facilities, and personnel

5. An outline of the trainer manual requirements and formats

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SPACECRAFT TEST OPERATIONS - DOWNEY

APOLLO DATA ENGINEERING

A briefing justifying the Apollo data engineering facility was prepared and presented to NASA at Houston on 25 April 1962. NASA has agreed with the requirements outlined.

BOILERPLATE DEVELOPMENT TESTS

A letter outlining the prequalification flight-drop aircraft and necessary facility requirements has been prepared for submittal to NASA. This letter is a consolidation of information previously submitted.

Facility Development

The design criteria for the house spacecraft acceptance area have been reviewed by all concerned organizations, and comments have been forwarded to the GSE facilities group.

Design criteria for the spacecraft operations and checkout building at AMR are currently being reviewed. Layout drawings for the Downey acceptance and checkout interim facilities are being prepared, and building occupancy schedules are being coordinated.

Apollo systems test representatives, accompanied by propulsion system and thermodynamics personnel, presented briefings on the proposed utilization of the Arnold Engineering Development Center to both NASA and AEDC personnel. The briefings concerned environmental/propulsion test facilities.

The design criteria for the airborne abort test program/Little Joe II (SID 62-488) have been reviewed, and comments have been forwarded to the GSE facilities group.

Instrumentation and Range Requirements

The instrumentation measurement requirements lists for the boilerplate abort test vehicles 6, 20, 12, and 23 were modified to reflect NASA inputs, test objective changes, and use of a command module tape recorder.

Range requirements for pad abort tests have been completed in rough draft format.

Apollo Test Program Plans

The revised test plan is being written, coordinated, and assembled, although the lack of a firm schedule and test objectives has been a critical element in the announced completion date of 15 May 1962. Lack of a firm schedule precludes the ultimate completion of detail test plans depicting test objectives, configuration, quantities of individual items of hardware, and GSE lists.

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DOCUMENTATION

MONTHLY PROGRESS

The following S&ID documents were published during April:

SID 62-354	Pretest Report For the 0.02-Scale Apollo Heat Transfer Model (H-1) In the 21-inch JPL-HWT (Revised)
SID 62-203	Reliability Program Plan
SID 62-154	Quality Control Plan
SID 62-400-1	Quarterly Progress Report
SID 62-384-3	Drawing List
SID 62-202	Maintenance Plan
SID 62-435	Transportation and Handling Manual
SID 62-77	Ground Operational Support System Equipment Performance and Interface Specification
SID 62-86	Telecommunications Subsystem Specification
SID 62-90	Flight Crew Performance Specification
SID 62-91	Spacecraft Systems Monitoring Personnel Performance Specification
SID 62-496	Earth Landing System Trainer
SID 62-497	Electric Power Supply Subsystem Trainer
SID 62-498	Command Module Reaction Control Subsystem Trainer
SID 62-499	Service Module Reaction Control Subsystem Trainer
SID 62-500	Launch Escape Subsystem Trainer
SID 62-501	Communications Subsystem Trainer

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SID 62-502	Service Module Propulsion Subsystem Trainer
SID 62-503	Instrumentation Control Subsystem Trainer
SID 62-504	Environmental Control Subsystem Trainer
SID 62-505	Navigation and Guidance Subsystem Trainer
SID 62-506	Stabilization and Control Subsystem Trainer
SID 62-507	Egress Trainer
SID 62-508	Weightlessness Procedures Trainer
SID 62-512	Lunar Base Operation Trainer
SID 62-99-3	Monthly Weight and Balance Report
SID 62-358	Training Equipment Requirements For Apollo Spacecraft (resubmitted)
SID 62-387	Mathematical Outline For Design Of Apollo Crew Training Equipment (resubmitted)
SID 62-401	Design Review Briefing (NASA request)
SID 62-423	Data Report For Wind Tunnel Tests (JPL 21-98) Of Apollo Models FS-1 and FS-7 (NASA request)
SID 62-460	Contract Data (revised)
SID 62-170-2	Apollo Wind Tunnel Program Report (revised)
SID 62-270	Contractor Interface Documents (revised)

The following type-I documents were revised for submittal to NASA:

Apollo GSE Specification, SID 62-50

Apollo Performance and Interface Specification, SID 62-57

Apollo GSE Design Criteria, SID 62-65

The preliminary Apollo Maintenance Plan was submitted on schedule. This plan delineates the detailed requirements for maintenance during factory (acceptance) testing, storage, assembly, and prelaunch testing.

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The preliminary Apollo Familiarization Manual was submitted on schedule. This manual describes the complete spacecraft, systems, and supporting equipment.

The first revision to the Apollo Support Plan is in progress; the tentative submittal date is 1 June 1962. Preparation of the Spacecraft Flight Operations Manual is progressing as scheduled.

A style guide for the preparation of support manuals has been completed and will be submitted to NASA for approval and subsequent inclusion in the definitized subcontractor work statements.

Definition of work statement requirements and rescheduling of support manual deliveries have been completed for transmittal to NASA for comment and/or approval.

Motion picture and still photographic documentation effort has been directed toward organizing the effort required by the Apollo Statement of Work. Progress to date includes the assigning of a single coordinator who reports to the Apollo Logistics manager and is responsible for the accomplishment of all Apollo contractual photographic submittals to NASA and the completion of the initial motion picture and still photographic submittal to NASA.

Preliminary photographic documentation planning is now complete for two major off-site testing events: the initial boilerplate drop tests (to be conducted by Northrop-Ventura) and the pad-abort tests (to be conducted by S&ID).

PLANNED ACTIVITIES

The Apollo Maintenance Plan will be revised to expand the information presented. Progress on the first revision to the Apollo Familiarization Manual will continue during the next reporting period. Coordination meetings with the major subcontractors have been scheduled to definitize documentation inputs to the Apollo Support Plan, Maintenance Plan, and Support manuals. Meetings will be continued, as firm requirements are defined by NASA.

Photographic documentation planning efforts will be accomplished for each significant testing activity conducted in the course of the program.

PROGRAM MANAGEMENT

Apollo Meetings held during April 1962 are presented in Table A-1.

Confirmation of the deletion of certain mock-up, boilerplate, and spacecraft articles from the Apollo program was received from NASA during the latter part of April. The following articles were confirmed as being deleted:

1. Mock-up 6—Partial service and partial adapter
2. Mock-up 13 and 14—Crew support and restraint
3. Mock-up 15—Handling and transportation
4. Boilerplate 4 and 7—Water impact
5. Boilerplate 10—Water egress and flotation
6. Boilerplate 11—Logistics equipment recovery
7. Spacecraft article 3—High-altitude abort

This communication from NASA also added another boilerplate to the schedule. This additional requirement specified as a metal, water tight article of the same shape and size as a command module with all external handling devices and with the capability for ballasting to full command module weight and center of gravity. This article will be used in developing adequate handling aids, procedures, and for training in water recovery of command modules.

Spacecraft 013 will be used for the second manned orbital flight.

The Apollo Master Phasing Plan has been revised to include program requirements as directed by NASA letter dated 18 April 1962 and amended 27 April 1962. The new Master Phasing Plan will be used as a basis for the firm Cost Proposal and will be included in the Program Plan.

SUBCONTRACTOR COORDINATION

Subcontractor letter contracts were placed with Avco Corporation (heat shield) and Thiokol Chemical Corporation (escape tower jettison motors) during April. This brings the total to eight:

1. Avco Corporation—heat shield
2. AiResearch—environmental control system
3. Collins Radio—telecommunication systems
4. Lockheed Propulsion—launch escape motor
5. Minneapolis-Honeywell—stabilization and control system
6. Northrop-Ventura—earth landing system
7. Pratt and Whitney—fuel cells
8. Thiokol Chemical Corporation—escape tower jettison motor

Negotiations for letter contracts have been completed with Aerojet-General (service module propulsion system) and Marquardt Corporation (reaction control system). Letter contracts are being prepared for these systems.

S&ID is negotiating with Northrop-Ventura (formerly Radioplane) and Douglas Aircraft Comapny for modification of the C-133A Aircraft. Attempts are being made to obtain the aircraft by bailment. Douglas must have the C-133A not later than 1 September 1962 in order to modify it and turn it over to Northrop-Ventura by 15 October 1962.

Surveys have been completed for the supercritical gas storage system, main and recovery batteries, and antennas. Procurement action for the inverter will start shortly.

ASSOCIATE CONTRACTOR RELATIONS

S&ID has selected project coordinators for each of the areas of associate contractor effort in the program.

Negotiations with MIT on the Apollo Associate Contractor Operating Procedure (SID 62-270) and the Apollo Interface Coordination and Control Methods Document (SID 62-271) were completed. The documents have been presented to NASA for approval.

Allocation of space for approximately 60 percent of the navigation and guidance system has been made in the command module. Space allocation for the balance of the system will be determined in future meetings.

MIT has provided preliminary layouts of requirements for its navigation and guidance facilities at S&ID and AMR.

Preparatory to the exchange of PERT data, S&ID and MIT held initial PERT discussions that were primarily concerned with the common definition of PERT terms.

The S&ID representative to MIT has been selected and will report to Cambridge in June 1962.

Some agreement was reached on the allocation of the navigation and guidance system.

Initial discussions were held with MIT on the philosophies of GSE, integrated systems checkout, testing, and quality control. Detailed discussions were held on the handling of navigation and guidance equipment. Coordination effort in these areas is continuing.

S&ID/NASA COORDINATION

Discussions have been held with Douglas Aircraft Company regarding the S-IV/spacecraft-adapter interface. Arrangements are being made to coordinate S&ID interface tooling with the existing Douglas tool master.

S&ID has participated in the first round of the MSFC-MSC Apollo-Saturn coordination panels. Permanent members are being selected and will be available to participate in subsequent panel meetings.

PERT

PERT coordination trips were made to NASA by S&ID personnel on 7, 17, and 30 April. Status of network preparation was reviewed, and overall progress toward previously established due dates was considered satisfactory by NASA. S&ID Program Control is continuing efforts toward completion of a cost reporting system related to PERT networks. Twice during April, PERT systems coordinators from S&ID visited associate and subcontractor facilities to assure uniformity of PERT approaches and concurrence in the requirements defined by NASA.

OPERATIONS RESEARCH

Studies for a reporting schedule and a procedure for processing data for the weekly report to NASA, a subcontractor reporting procedure, and an event numbering system were initiated during April.

CONTROL ROOM

The utility of the Apollo control room was greatly expanded during April. Color-coded charts giving pictorial representation of manufacturing sequence progress of the first unit of each of the major modules of the spacecraft have proved effective.

STABILIZATION AND CONTROL SYSTEM

A preliminary analog computer investigation was conducted to evaluate various proposed entry-control systems, to optimize the most promising configuration, and to determine the optimized system performance/fuel consumption ratio as a function of attitude commands and dynamic pressure. The most significant outputs from the study are definition of the duty cycle of the reaction jet engines in the command module (i.e., fuel-consumption distribution as a function of pulse widths) and the determination of total fuel costs for performing step-command roll maneuvers in the entry dynamic-pressure envelope. (See Figure 4.)

Control system configuration analyses and the development of the equations of motion are in progress for subsequent analog computer studies.

A control system configuration for executing Euler angle attitude commands that will accomplish large-angle slewing in an attitude mode with minimum fuel consumption is being studied.

Root-locus studies of the escape vehicle dynamics have been derived for the control system analysis. Nozzle configuration/structural design trade-off studies have established nozzle locations in the launch escape system.

Quantitative trade-offs between the single- and four-engine, service-engine control systems are still in progress.

An investigation is being conducted to determine the performance of proposed pulse modulation schemes in the presence of typical midcourse disturbances.

FACILITIES

Specific facility requirements have been defined by area locations. Equipment and instrumentation procurement specifications and requests are being prepared.

SUBCONTRACTOR RELATIONS

S&ID, Minneapolis-Honeywell, and MIT have jointly prepared a matrix of guidance and navigation requirements to be imposed in the attitude control system during coast operation.

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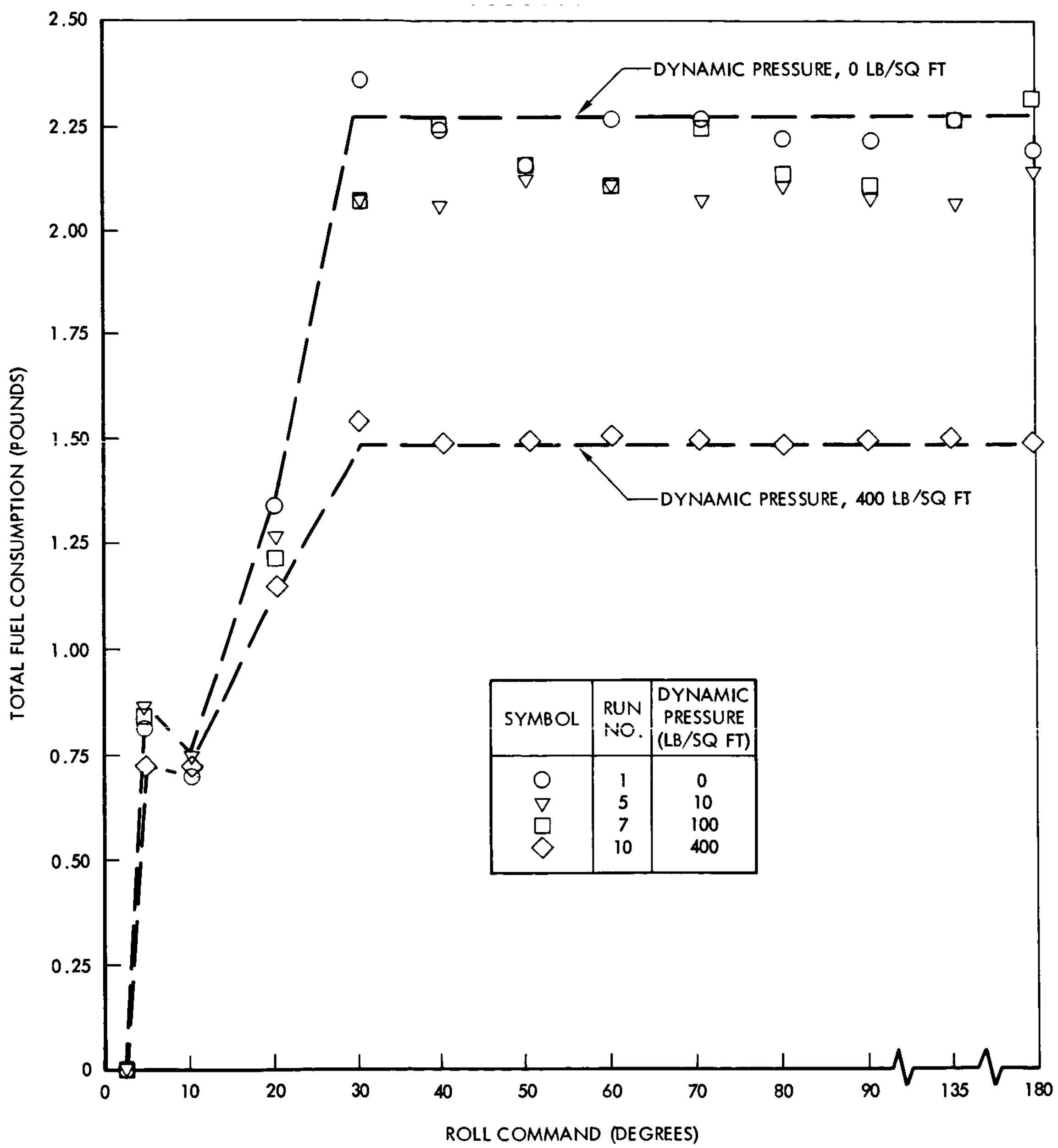

Figure 4. Entry Maneuver Fuel Costs

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PLANNED ACTIVITIES

Requirements for breadboard system tests are being prepared, and better definitions of the experimental evaluation program will continue as a prime effort.

A study of the interfaces between the stabilization and control system and the guidance and navigation system during coasting will be completed.

A model for defining disturbance torques during the coast operation will be completed this month.

The procurement specification for the stabilization and control system will be completed and released during the next reporting period.

CREW PROVISIONS

MOCK-UP

During April, sustained and concentrated effort was devoted to the refurbishment of obsoleted command module mock-up 1. This effort, requested by Life Systems Engineering, was expended so that this mock-up and a supporting GSE console would reflect the latest configurations for preliminary manned-machine system analysis, design, and evaluation. On 19 April, NASA conducted a design review of this mock-up, now designated simulator 1. This simulator will be maintained in conformance with the latest configurations of life systems engineering. The same maintenance effort will be devoted to command module mock-up 1, which is virtually complete in structure and which will be designated simulator 2.

CABIN ARRANGEMENT

The anthropometric grid for pressure suit and cabin arrangement measurements has been completed and installed in the work-space analyzer room.

Design criteria for the airlock step configuration have been completed.

CREW COUCH DESIGN

Drawings for the crew couch, as well as pad fabrication and installation for the three crewman couches in simulator 1, have been completed.

PERSONAL EQUIPMENT

An evaluation has been started on crew-stabilization techniques that are integral with crew personal equipment. VELCO samples have been obtained for testing purposes.

A Mark-IV pressure suit for mobility and measurement tests has been borrowed from AiResearch. Hardware to simulate pressure suit interface and mobility tests and to establish requirements is being obtained.

Studies have been initiated on personal hygiene equipment and storage area requirements for simulator 2.

The pressure suit-spacecraft interface specification, SID 62-223, has been completed.

FOOD MANAGEMENT AND WATER SUPPLY

Simulator-test diet procedures have been established. A diet and menu selection outline has been prepared.

Requirements for food storage, wash storage, and water provisions for simulator 1 are being developed. An evaluation of the possible use of fuel-cell water has been initiated.

WASTE MANAGEMENT

A preliminary analysis of urine storage and a trade-off matrix on urine management problems have been completed.

Analyses are being conducted on bacterial survival in a hard vacuum and microbiological control problems.

CREW ANALYSIS

An analysis of the visible environment outside the capsule is being conducted.

A work-rest cycle report is being completed.

A definition of problems associated with the biomedical aspects of countdown and checkout has been prepared for use with GSE design analysis. A preliminary format for a human-factors, GSE checklist has been completed.

A criteria list for the selection of subjects for crew performance studies has been prepared. Criteria for medical examination of simulator subjects have been established.

An evaluation of exercise and cardiovascular adaptability is being made.

A list of emergency medical equipment has been prepared for the analysis and study of simulator 2.

Prelaunch operations from T-480 minutes to T-0 minutes are being analyzed to establish criteria and requirements for countdown operations.

A preliminary study establishing recommended noise levels within the command module has been completed.

CONTROLS AND DISPLAYS

Lighting requirements have been drafted for interior and panel lighting of the command module.

A final control display layout for simulator 1 was designed, fabricated, and installed. This layout, showing the location of warning, caution, and advisory lights for simulator 1, was shown at the design review meeting held at S&ID.

LABORATORY SUPPORT

The defining of laboratory support requirements to life science activities awaits further development of the requirements for crew provisions. However, preliminary studies have been started on the fabrication of specialty containers for waste products and for impact attenuating materials for chair cushions.

PLANNED ACTIVITIES

The following activities are planned for the next report period:

1. Extensive planning and coordination in the area of controls and displays
2. Formulation of make-or-buy specifications for personal equipment
3. Preparation of drawings for mock-ups 10 and 12 and boilerplates 1, 3, and 19
4. Analysis and study of GSE and in-flight maintenance and automatic programing for a crew task analysis
5. Continued development of methods for analyzing crew performance in terms of information rate and content
6. Development of an airlock mock-up for use in checking pressure suit clearances and in detailing egress-ingress requirements
7. Study of pressure valves and work-space requirements of the airlock mock-up
8. Development of materials and processes for biosensors, simulated viscera, and moulages
9. Procurement and compilation of property data on biologically inert materials

LAUNCH ESCAPE SUBSYSTEM

LAUNCH ESCAPE TOWER

A program was initiated for the selection of either titanium alloy (6AL-4V) or precipitation-hardenable steel (PH 15-7 Mo), heat-treated in accordance with S&ID process specifications. The producibility of these materials was evaluated, and titanium alloy tubing was selected for the tower structure. Of the materials investigated, titanium exhibits the highest strength-to-weight ratio and affords good elevated temperature resistance (to 1000 F). A test program to determine the strength of cluster, tube-welded joints has been started. Completion is scheduled for 15 May 1962.

Changes in the proposed tower structure have caused a relocation in the centerpoint pyrotechnic-cable cutter.

Detailing of boilerplate parts was started this month. A design layout has been completed for the latch and release mechanism. A study is under way to determine the feasibility of using two of the four escape tower latch mechanisms in C-133 drop tests as a means of holding and releasing the command module.

FABRICATION

Detail fabrication on the launch escape tower is scheduled for early May. NASA requirements for this subsystem have not yet been defined to the extent that engineering can support the manufacturing schedules.

LAUNCH ESCAPE ROCKET

A study of the thrust vector control (TVC) system of the launch escape motor indicates that the hinged-nozzle system has both a weight and a reliability advantage over the secondary injection system. However, final system selection awaits NASA's approval.

Plans have been initiated for the experimental evaluation of the stabilization and control system. Instrumentation specifications for this system are being prepared since early evaluation is programmed. The coordination of facility requirements is continuing.

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TOWER JETTISON MOTOR

Layouts have been completed on the LES jettison motor-to-nose cone and the jettison motor-to-LES motor adapter interfaces and on the motor adapter. The principal changes from the proposal configuration were that nozzles will be faired to a 14-in.-radius mold line (extending 1 in. beyond the 26-in. motor diameter) and that 1-deg yaw angle thrust vector will be built into the motor.

STRUCTURAL DESIGN

The LES configuration was approved by the design review board. The approved configuration is based on wind-tunnel test information. It embodies a 120-in. tower, a symmetrical nose cone, a jettison motor located forward of the launch escape motor, and an aerodynamic skirt covering the escape-motor nozzles. This configuration change in the escape rocket nozzle cant angle increases the nozzle cant from 19 to 33 deg to the axis of the rocket, as depicted in Figure 5. Thus impingement of hot gases on the command module is precluded. A method of preloading the attachment stud to the command module has been established, and a detail layout of this configuration is in progress.

The design layout of the lower structure of the launch escape tower is in progress. A boxbeam-type cross-member will be provided to house the tower-release mechanism cables, cable cutters, and turnbuckles. Hinged doors will be provided for access.

Detail design studies are continuing on the LES tower-to-command module attachments and release mechanism. The cables for the release mechanism will be routed along the sides of the tower and will be designed with maintenance provisions.

Preparation of the first detail drawing of the LES motor-to-tower adjustable attachment fittings has been initiated.

A layout of the nose cone that includes provision for installing the lead ballast has been started.

The detail drawing of the launch escape tower truss structure is in progress and on schedule.

STRUCTURAL ANALYSIS

A study was initiated to determine a method for evaluating the secondary stresses induced in the truss member by joint rigidity. As a result of this study, a new cross member configuration for the lower truss structure was evaluated.

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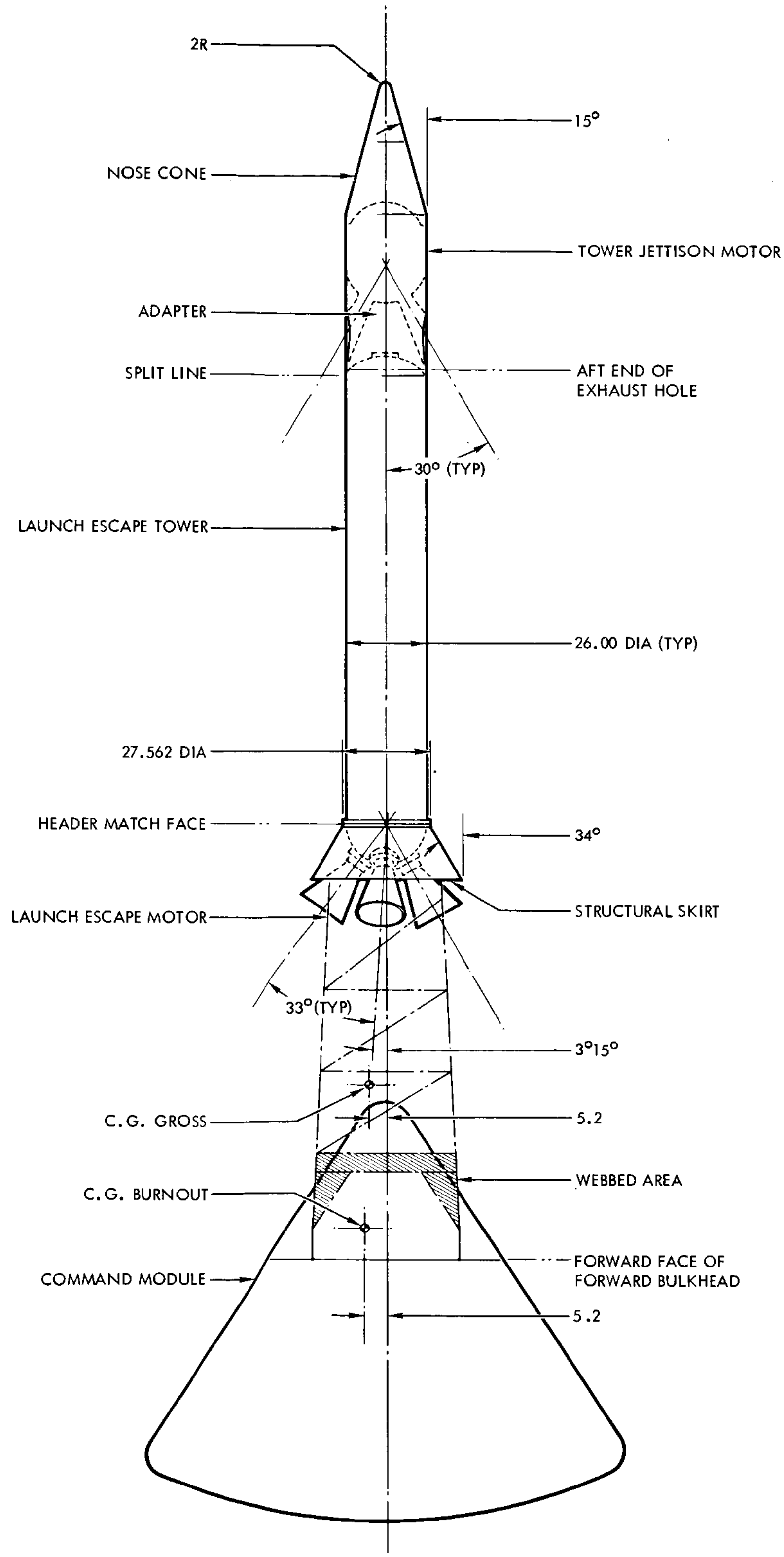

Figure 5. Apollo Launch Escape System Configuration

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S&ID completed a deflection study in support of the natural frequency calculations. The results of this study indicate the deflection of each truss joint due to unit shear, unit axial, and unit moment loads.

A study is being made to reduce the openings in the command module where the launch escape tower mounts to the forward bulkhead. An analysis is being conducted on the LES-to-command module release mechanism. Methods by which the stiffness characteristics of the tower structure can be calculated are also being considered. Layout work is now in progress on the centerpoint cable-release system.

The sizing of the lower-release mounting flange is complete, and sizing of the rocket motor-to-tower attach skirt is continuing.

The sizing study for the most recent tower loads was completed, and various tower configurations were compared.

Material and producibility constraints were imposed on the tower design, and the weight penalties associated with the use of a constant tube thickness and constant tube diameter were assessed. These tests resulted in a decision to fabricate the tower structure from two tube sizes.

Insulation-weight trade-off data were combined with a weight-versus-temperature structural-weight study. Results of this combination indicate that minimum insulation and structural weight occurs at a temperature of 600 deg F; this implies an insulation-weight penalty of about 180 lb for a thermolag insulator.

The launch escape tower is being studied for a torsion resulting from the rocket motors being swivelled ±10 deg. (This torsion may be combined with present abort conditions.) An investigation has been started to determine what weight penalty would be imposed upon the structure by the torsion.

WEIGHT CONTROL

A weight-and-balance study of the LES was performed so that an optimum system configuration, consistent with flight stability, would be selected. The minimum weight has been determined. Each configuration was ballasted to the centers of gravity which were specified to have an adequate stability with varying tower lengths. Results of this study are presented in Figure 6.

The current weight for the 120-in. tower structure configuration is 5600 lb, including a 168-lb ballast for a 0.61-deg center-of-gravity location and a 4471-lb main thrust motor.

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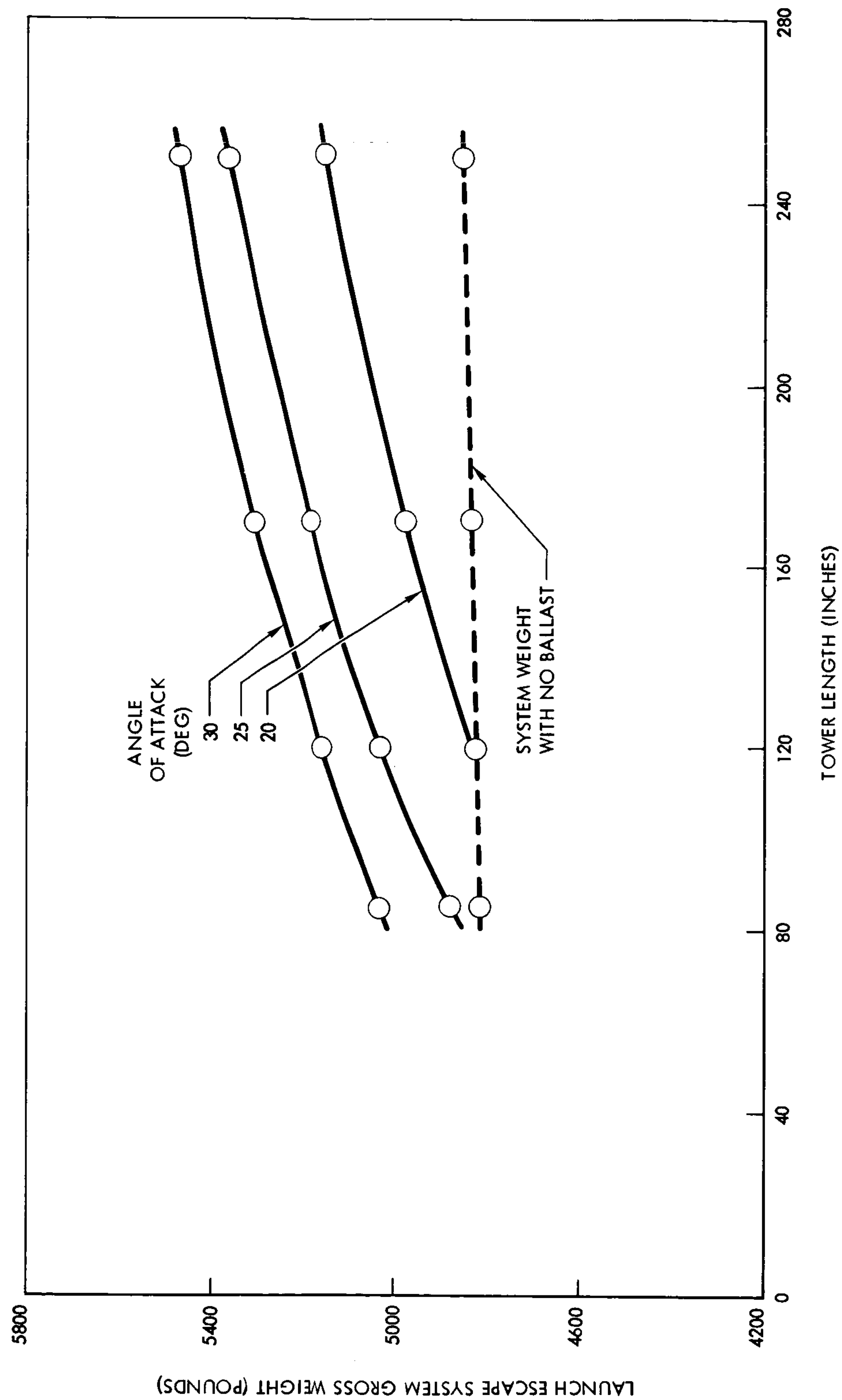

Figure 6. Launch Escape System Gross Weight Versus Tower Length for Various Maximum Stable Angles of Attack

Inertias, weights, and centers of gravity are being computed for the 120-in. configuration with five main-motor burning times, with loaded and burned out jettison motors, and with/without ballast. These will be combined with the command module for the abort-stability studies.

Cost-analysis weight statements have been completed for all the spacecraft configurations; they are being issued in report form.

MOCK-UPS

Preliminary studies indicate the feasibility of using a prototype structural design of the escape tower for mock-up 9.

PLANNED ACTIVITIES

Work will be started on the escape tower for mock-up 9.

An advance sketch showing the material requirements for the escape tower assembly will be issued.

ENVIRONMENTAL CONTROL SYSTEM

SUBCONTRACTOR ACTIVITIES

As a result of an intensive study of the basic system requirements, the environmental control system (ECS) schematic was modified. This modification eliminates unnecessary redundancies; achieves a greater degree of component integration; reduces weight; and, in general, increases system effectiveness.

Revisions of the documents applicable to the schematic changes for a minimum of repetition and a maximum of complementation are being made.

WATER MANAGEMENT SYSTEM

The revised water management system reflects the most recent requirements for spacecraft cooling and potable water provisions. The major changes were

1. The cooling water capacity requirement was reduced.

2. The potable water and the cooling water needed during boost were combined into one tank in the command module.

3. The requirement of a water blanket, for protection from radiation, was eliminated.

It was also decided that one tank in the service module would be used to store the greater portion of the cooling water. However, studies are being made to determine the feasibility of storing all cooling and potable water in the command module. This study was undertaken in response to a recent NASA decision to reduce the capacity of the urine tank; this study also considers the effects of a night, as well as a day, lunar landing.

LIQUID COOLING SYSTEM

Since the lunar supplemental refrigeration system and the adoption of deployable radiators were eliminated, significant changes were made in the water-glycol coolant system. The coolant loop regenerative heat exchanger has been removed from the service module. A liquid valving arrangement replaces the gas-leak-check provision at the radiator panels. Furthermore, the circuit is now completely cascaded in regard to the suit-circuit heat exchanger, the cabin heat exchanger, and the electronic component coldplate. In addition, a small, regenerative heat exchanger has been added in the command module to preheat the water-glycol. A separate coolant branch to the inertial measurement unit section of the electronic system provides for the more critical cooling task required in that area.

Component integration produced a more compact packaging arrangement; e.g., the coolant pumps and reservoirs were incorporated into a package and the glycol water-to-air heat exchanger and pressure suit loop water evaporator were integrated into a three-fluid heat exchanger containing air, water, and glycol-water passages.

A laboratory investigation has been initiated to determine feasibility of fabricating aluminum coldplates by an aluminum dip-brazing method. Test specimens are being designed to define the minimum/maximum dimensions for the cross-sectional area of the cooling passages and flatness of the plates. Tests are being conducted to determine flow patterns, temperature profiles, coolant resistance, and other thermophysical properties.

PRESSURE-SUIT CIRCUIT

Several improvements have been evolved for the pressure-suit circuit. A single, common bypass has replaced the three individual suit bypass lines. One more suit inlet-outlet unit has been added to the sleeping quarters. The cabin fan location has been shifted so that it now operates as an intake fan during the post-landing phase. The single charcoal filter, which formerly was placed in parallel with the lithium hydroxide canisters, has been replaced by charcoal filter elements in series with each of the canisters. A diverter valve and two check valves have replaced the four isolation valves at the water separator. The demand-oxygen connection has been relocated to the low-pressure point of the suit circuit. This placement minimizes undesirable pressure transients caused by the admission of oxygen to the circuit.

CABIN ATMOSPHERIC CONTROL

More effective evacuation and pressurization of the airlock system was obtained by valve modifications. Redundancy was reduced in the pressure regulation of the re-entry oxygen supply system, and provisions were made for pressure relief into the suit circuit.

Laboratory research indicates that ultraviolet radiation poses greater problems to the interior finish than vacuum conditions do. Continuing evaluation is being made on the radiation problem.

WASTE MANAGEMENT

Studies are being conducted to implement the recent NASA decision to reduce urine storage provisions from 14 days to 1 day. This reduction results in a weight savings of approximately 100 lb. Disposal to space, rather than storage, is now planned. Investigations have been planned to determine whether or not more frequent dumping is possible.

TESTING

The design of a test chamber to house the ECS breadboard has been started, and a digital data logging system for the conduct of breadboard tests is under evaluation. Procurement specifications have been prepared. Additional equipment and instrumentation requirements are being defined. Detailed test plans and procedures are being prepared.

MOCK-UPS

Drawings of the ECS components of mock-up 5 (cabin exterior) have been released. Drawings are being prepared for mock-up 10 (command module interior). All available dimensional outlines are ready for design incorporation into mock-ups 2 and 3 (cabin interior arrangement) and mock-up 7 (complete service module).

PLANNED ACTIVITIES

Continued revision of documents applicable to basic system requirements.

Investigation of the feasibility of storing all cooling and potable water in the command module.

Consideration of the effects of night and day lunar landings.

Exploration by the laboratory of the properties of system components.

Studies to determine optimum methods and frequency of waste disposal for the reduction of system weight.

Defining test procedures and facilities.

EARTH LANDING SUBSYSTEMS

SUBCONTRACTOR ACTIVITIES

S&ID is negotiating with Northrop-Ventura (formerly Radioplane) and Douglas Aircraft Company for modification of the C-133A Aircraft. Attempts are being made to obtain the aircraft by bailment. Douglas must have the C-133A not later than 1 September 1962 in order to modify it and turn it over to Northrop-Ventura by 15 October 1962.

PARACHUTES

S&ID determined that two pitch motors can be located on the Z-Z axis of the parachute compartment.

A study of drogue mortar firing load and capsule reaction indicated negligible effect on the capsule.

The parachute riser release system will employ a single-point release at the upper bridle-torsion riser point. This system leaves the bridle attached to the command module and incorporates a standing loop to facilitate recovery hoisting. The riser attach mechanism has been detailed.

DROP TESTS

Final agreements were made to use a modified C-133A for aerial drop tests. Boilerplate 1, 5, and 19 will be tested.

SEPARATION SYSTEM

Major volume requirements in the forward compartment have been determined for the system that will separate the heat shield from the command module. The system concept involves a multipoint tie-down with mechanical latch release and heat shield propulsion by arrangement of manifolds. The ejector cylinder hatch release and initial impulse are self-sequencing.

Equipment locations have been established. Configuration of the gas generator-cable cutter has been defined and preliminary sizing has been accomplished, and methods of load application and load-points have been established.

IMPACT ATTENUATION

Command Module

A new configuration has been developed to be used on all boilerplates, except 1 and 3. This new configuration was necessitated by a mold-line change for the inner structural sidewall. This change will require a revision of both shock struts.

The new configuration incorporates an increased horizontal stroke for greater horizontal energy absorption. It also incorporates load distribution data from a new analog computer program that simulates the shock strut characteristics and the elastic properties of the command module and the soil.

Prior to the issuance of the new mold line, the configuration of boilerplates 1 and 3 was frozen. The horizontal and vertical shock struts for these boilerplates have been designed, and an installation drawing has been completed. Detail design work is proceeding on the shock struts of the new configuration. The term "airframe" (AFRM) shall be used henceforth to designate command module design.

Crew

A concept for shock attenuation along the Y-Y axis using crushable aluminum honeycomb material was evolved. A cylinder, mounted on the outboard edge of the outboard couches, mechanically extends to bear against the side equipment compartments walls.

Shock strut designs are complete in all three axes for boilerplates 1 and 2.

The Z-Z attenuator was redesigned to incorporate an interchangeable strut-end for water landings.

For boilerplate 1, the X-X axis struts are structurally designed to 26.6 g despite the fact that they cannot be loaded in excess of 20 g and had originally been functionally and structurally designed for the lower figure. Individual shock strut development tests have been written. These tests require a drop tower, a means for statically loading the struts prior to drop, and instrumentation to record load and stroke data.

FABRICATION

Prints were released this past month for the impact attenuation system of command module boilerplates 1 and 3, and for the seat attenuation system of boilerplates 1 and 2. The vertical (air-oil) struts will be purchased, and quotations are in and being processed. Material has been purchased for in-house fabrication of the horizontal and seat struts, which are scheduled for completion in May.

AFT HEAT SHIELD RELEASE MECHANISM

Detail design of the aft heat shield release mechanism has been started. This design employs a latch that fits around the impact attenuation vertical strut barrel and bears against two projecting lugs on the barrel. The latch is restrained by two open toggles and a cable in tension. The cable is released by a single cable cutter. This design will be used on boilerplate 3 and may be used, with minor revisions, on others.

PLANNED ACTIVITIES

A program to establish ejection requirements for the upper compartment cover has been developed. The requirements will be determined by investigations of the cover trajectory after release from the command module.

The design installation of the drogue mortar is being studied so that a coordinating envelope specification can be prepared for Northrop-Ventura, who will design the mortars.

COMMUNICATION SUBSYSTEM

SPECIFICATIONS

The service module antenna system specification is near completion. The telemetry radome procurement specification for Saturn-9 and subsequent vehicles is in preparation.

REQUIREMENTS

An investigation is being made to determine what equipment can best be operated from a 115-v, 400-cps inverter supply. A thorough instrumentation and equipment review reflected the need for an increase in laboratory equipment requirements to support the evaluation program. New equipment and additional area to accommodate the communications evaluation effort are being sought.

MODULATION TECHNIQUES

S&ID and Collins Radio personnel met to discuss results of the modulation technique studies and to arrive at a preliminary decision on the technique for the deep space instrumentation facility (DSIF) link. No decision was made because the two companies differed in basic assumptions on modes of operation, safety factors, frequency allocations, duration of ranging requirements, and the unresolved question of analog versus digital television (TV) transmission.

Evaluation of the two optimum modulation-reception techniques showed that 20 w of DSIF link transmitter power is barely adequate for transmission of the equivalent of one megacycle baseband television by either digital or analog means. Increase of the system margin is being sought through the optimization of link design procedures. The means of synchronizing the television signal were studied, and an acceptable technique was selected.

TELEMETRY

The feasibility of in-flight programing for the pulse-coded modulation (PCM) telemetry system is under investigation, primarily from the standpoint of measurement requirements per mission phase. In-flight programing could be advantageous, particularly for the lunar landing mission.

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ANTENNAS

Procurement specifications were released for pad abort, Little Joe II, and Saturn-5 through Saturn-8 vehicles.

Models of a one-third-scale command module and tower are being fabricated for usc in the antenna pattern study that includes a determination of the effects of the abort tower on discone antenna patterns and impedance. Radio frequency power breakdown of the discone antenna is also under study.

RADIO RECOVERY AIDS

Trade-off data are being generated to firm up the radio recovery aids configuration. Data are being gathered on existing recovery beacon equipment and on existing aircraft receiving equipment.

STUDIES

S&ID has initiated study to define the minimum bit rate for acceptable digital TV, the minimum bandwidth for acceptable analog TV, and the definition of a minimum spacecraft TV system of each type.

Coordination of the analog-digital TV studies has been directed toward ensuring that the evaluation method chosen will give valid comparison data.

S&ID has studied data concerning a modulation-tracking, phase-lock detector for TV reception.

PLANNED ACTIVITIES

Specifications for the service module antenna system will be completed. Procurement specifications for the telemetry radome are to be completed. A preliminary report and recommendations concerning modulation techniques will be issued. Further work is planned to define radio recovery aids.

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NAVIGATION AND GUIDANCE INTEGRATION

SYSTEM ANALYSIS

Re-Entry

A preliminary approach for a backup entry guidance mechanization is being formulated for situations of total failure or unavailability of the guidance system. The system under study is essentially a strap-down system with no computer. Three steering methods are being considered.

Investigation to determine the conditions that will give a closed-form solution to the equations of motion for entry for the primary mode study are proceeding. The accuracy of this solution will be investigated to determine the sufficiency of the solution for re-entry guidance. The MIT and Ames re-entry steering equations are being studied.

Launch Abort

A study has formulated and derived concepts and a thrust program for launch abort to result in minimum g loads at entry. The study included the consideration of finite engine thrust and finite time for separation and orientation of the command module prior to dynamic pressure buildup.

Guidance Computer

S&ID conferred with MIT on the logical and electrical organization of the guidance computer. The IBM 7090 program for the simulation of the guidance computer was initiated. This program will be employed in determining the accuracy and method of mechanization for the different phases of the Apollo mission.

Midcourse guidance mechanization is being investigated from two approaches so that the relative complexities of mechanizations in the MIT guidance computer can be determined.

Radar

Preliminary study of radar installation and of environmental and operational problems of the radar antenna produced some basic design and location criteria.

Short preliminary studies were made of methods of establishing local vertical, vehicle attitude requirements and of determining the vehicle velocity vector with a single-beam, Doppler radar system for lunar landing. The types of radar to be used for rendezvous and lunar landing guidance are being sought in these studies.

COMPUTER ANALYSIS

An analysis of the application of zeta transformation to analysis of numerical algorithms is complete for the case of forward-loop digital systems. Two additional cases, closed loop digital and forward loop digital-continuous, are being considered. These greatly extend the utility of the methodology.

The problem of digital system error analysis for sources of error other than numerical algorithms indicates that the propagation of truncation errors can be analyzed in terms of the eigenvalues of appropriate operators. However, a general means must be established for obtaining these eigenvalues as a function of the number of operations. This problem will be studied.

DESIGN INTEGRATION

The optimum location for the inertial measuring unit (sextant-telescope) was determined to be the center part and forward section of the lower equipment bay. The telescope will penetrate the pressure hull at this point.

The installation of the computer and electronic components in the lower equipment bay is under study. Two locations are being considered for the other display and control items.

FACILITIES

Facility requirements, including instrumentation and equipment, essential to the support of navigation and guidance efforts were given special attention. Procurement specifications are being prepared for the requisition of equipment and instruments.

PLANNED ACTIVITIES

Continued study of steering methods for backup entry guidance.

Completion of the study of zeta transformation to analysis of numerical algorithms.

Further studies to resolve problems of digital system error for error sources other than numerical alogrithms.

Continuation of study of midcourse guidance mechanization.

Completion of navigation and guidance system performance requirements specification.

Additional checkouts of the program for comparison of data filtering techniques using on-board optical measurement for orbit determination.

Determination of rendezvous and lunar landing radar types.

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COMMAND MODULE STRUCTURE AND SUBSYSTEM INSTALLATION

BRAZED HONEYCOMB SANDWICH STUDIES

Tests on five brazing alloys for René 41 alloy indicate good wetting and no difficulty in producing brazed joints, and remelt temperature tests indicate useful service above 2000 F. Tests on three experimental brazing alloys for honeycomb sandwich fabricated from the L-605 cobalt alloy indicate satisfactory brazing.

ADHESIVE BONDING

Basic application and environmental parameters for adhesive bonding have been defined.

MOCK-UP

The command module mock-up 5 (cabin exterior equipment) was completed on schedule in April. Exterior equipment for mock-ups is being fabricated and installed on schedule. Final detail drawings to complete the structure of mock-up 2 and 3 have been received. The aft heatshield dish pan for mock-up 9 and other details of the article are being installed. Work on mock-up 8 was scheduled in late April. Mock-up 2 and 3 are expected to be complete early in May; mock-up 7 will be completed later in the month.

Work on command module boilerplate articles 2, 3, and 19 began in April. After delivery of the aft bulkhead in early May, boilerplate 1 effort will be accelerated. Boilerplates 5 and 20 are scheduled to go into work in May.

Tooling effort in support of all command module articles progressed rapidly in April. Three fixtures and a jig were completed during the month; this brings the total of tools now complete to seven. The five other necessary jigs are approximately 60 percent complete, and all are scheduled to be completed in May. Another tool, the plaster master model of the spacecraft command module, is rapidly taking shape and will be completed in sections to support the mold-line requirements of the suppliers of brazed honeycomb panels.

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THERMOPHYSICAL PROPERTY MEASUREMENTS

Thermal conductivity and mean specific heat determinations are complete for the four phenolic-based ablation materials considered for use on the command module heat shield.

MECHANICAL PROPERTY TESTS

A report covering the mechanical properties testing for Haynes 25, cobalt-base-alloy honeycomb specimens has been completed.

SEALS AND SEALANTS

A literature search on elastomeric seals for use in outer space has revealed the following environmental considerations: radiation effects; sublimation rates; and permeability and physical rates before, during, and prior-to-completion of high-vacuum exposure tests. Studies have been completed on permeability and its reduction by compounding, and test procedures are being reviewed to determine permeability rates associated with the environment.

FULL-SCALE COMMAND MODULE STRUCTURAL-THERMAL TESTS

A program to determine a satisfactory method of installing thermocouples in ablative materials and to verify a shaved ablative method of testing for the command module heat-shield test has been initiated. An ablative of reduced thickness gives the same structural properties, at a particular time during re-entry, as the actual heat shield. This allows the programing of thermal input to the shaved ablative to be controlled by thermocouples at a much smaller total power requirement, which falls within the capabilities of the S&ID radiant heat facility.

STRUCTURAL ANALYSIS

Analytical efforts continue to support design considerations for many detailed problems on the command module inner shell and outer shell structures. Other analytical work performed during this month is reflected in Table 8.

STRUCTURAL TESTS

The Stresskin panel evaluation program began with investigations of panels fabricated of the PH15-7Mo Cress alloy.

Critical loading requirements for the structural component evaluation test of the command module are being investigated.

Table 8. Command Module Structural Analysis

Component	Procedure	Purpose or Determination
Forward bulkhead	Comparison of stiffness of the sandwich and longerons stress and deflections in this component and in the airlock and of three conditions of the inner edge of the bulkhead	Analysis of integration with adjoining wall, longeron, and airlock and analysis of the connection of outer edge to side wall
Sidewall heat shield	Thermal analysis (rigid attachment of heat shield to inner cabin structure)	Preliminary data indicates circumferential expansion is lighter than radial expansion
Upper compartment	Calculation of load and strength factors	Requirements
Aft heat shield	Reaction of ground impact forces on individual pads made integral with the heat shield and located at each shock strut	To determine compatibility with a shock strut system, required extension in addition to normal stroke, resultants from structural deformations, and the lightest arrangement
GSE adapter	Calculation of load and strength factors	To determine structural integrity under ground handling loads
Electrical impulse	Rough distribution for entire spacecraft	To support structural dynamics studies
Longerons	Prototype drawing under analysis	To determine structural requirements
Shock strut assembly	Boilerplate drawing	To determine structural requirements
Honeycomb sandwich panels	Generation of physical geometry and properties data	To support study to determine thermal gradients for various heating rates.

STRUCTURAL DESIGN

A method for incorporating the shock-strut attach fitting with the longeron and kick frame splice has been developed for the forward sidewall. A major portion of the compression load from the shock struts is taken in direct bearing by the attach fitting on the longeron.

The structural diagram was revised to reflect changes resulting from canting the aft sidewall. A basic design for the umbilical cans and their relationship to the service-to-command module shear support fitting is being developed.

The inboard beams of the aft bulkhead were relocated to pick up the repositioned aft sidewall members. To prevent introduction of a moment in the sidewall, a simple shear-tie approaching a pin-end will be used for the end ties of the aft bulkhead beams.

The layout of a ladder is complete; it has been incorporated in the airlock mock-up for evaluation. Provisions for mounting environmental control system (ECS) equipment are being studied.

Design studies on installation of the crew and the equipment compartments are continuing.

A crew hatch size large enough to install the movable airlock has been determined. Space limitations were resolved by canting the aft sidewall so that the kickframe could move aft to increase the length of the forward sidewall.

Work to develop observation window criteria basic for the design of size and for the determination of location for optimum vision has been started.

HEAT SHIELD

The layout defining all known penetrations is being revised to reflect relocation of attitude control motors, service module tension ties, and umbilicals.

Differential Thermal Expansion

The two most feasible approaches to the resolution of the problem of differential in regard to the inner-to-outer structure are defined as conical and shingle expansion.

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Basic design configuration of the forward compartment was changed by the relocation of the two attitude-control engines to this area. Design studies will resolve this installation problem. Provisions are being made for access to fuel line disconnects and for the sealing of the motor housing.

Several changes in area layouts for the crew compartment were made because of the relocation of the attitude control engines from the lower to the upper crew compartment area. The engines were repositioned in the upper crew compartment area, where less heat flux during re-entry is experienced.

A segment of the aft compartment was structurally changed from brazed honeycomb to sheet metal construction. The substitution that occurs in the forward conical substructure segment provides for the 3 in. of lateral displacement required during landing impact attenuation.

SYSTEMS EQUIPMENT INSTALLATION

Crew Compartment

Partial agreement on navigation and guidance equipment location was reached after a series of conferences between S&ID, NASA, and MIT. A control layout has been completed for all umbilical connections to the command module.

Aft Compartment

Changes in the tanks and equipment are reflected in a completed control layout.

Launch Pad Service

S&ID has requested modification of the Army Ballistic Missile Agency (ABMA) concept for booster service on launch pad 39 at AMR . As conceived by ABMA, service at this pad would be accomplished only through a single arm that would extend from the umbilical tower opposite the command module crew hatch. S&ID requested either a single, movable service arm that would enclose the Apollo spacecraft or two separate arms (one for each module) that would enclose the modules. Studies are being made on servicing requirements for the modules and for the assembly, transportation, and servicing capability of launch pads 34, 37, and 39 for the complete launch vehicle with the Apollo spacecraft.

Mock-Up

An engineering sketch to fabricate a universal mock-up handling dolly was prepared. The dolly will be capable of transporting both modules and the adapter. The command module GSE adapter is being analyzed so that structural integrity under ground handling loads can be determined. Mock-up 9 and 11 are being checked for possible types of ground handling loads. The mock-ups are being sized so that they may be handled by using either the launch-escape tower fittings or the command-to-service module umbilical tie points.

Boilerplates

The beam and carry-through fittings at the couch interfaces are being redesigned to incorporate an integral splice for attaching the main cross beams. A revision has been made to the inboard back beams to incorporate the A-A axis attenuator fitting as an integral clevis.

A basic couch and shock attenuation system for the boilerplate has been established. The armrest and handrest drawings have been released. The knee attenuation fitting drawing is being completed. Work is progressing on the shoulder beam couch fitting, the headward attenuation fitting, and the footrest assembly.

Prototype

Two static analyses of the prototype aft heat shield have begun. One is a simplified solution to make the heat shield analysis statically determinate. The other is a redundant analysis that uses present programs on the IBM 7090. Both of these analyses assume a buckled center portion of the heat shield.

Shock strut loads were calculated for various capsule attitudes for both maximum horizontal load factors. A study was made to determine the ability of the rim of the heat shield to beam the impact loads to the aft struts. Results indicate that for high horizontal load factors or for large pitch angles, the rim of the heat shield, as presently conceived, will not resist the loads.

The prototype parachute support longerons have been relocated to provide proper alignment with the center of gravity of the vehicle. Four longerons in the area of the forward bulkhead have been redesigned to accommodate the attachment of the nose cone. The airlock-to-forward bulkhead attachment has been revised to ensure that no moment is introduced into the end of the airlock cylinder.

Work continues on the crew access hatch latching mechanism. The concept of a door that draws down from above, uses interlocking flanges on the sides and top, and requires latches only along the bottom sill is being studied. A series of worm-and-pinion lead screws is now under consideration.

PLANNED ACTIVITIES

Studies of forging design and alternate methods of fabrication will continue.

Firm locations will be established for equipment so that the center-of-gravity studies of the command module can be made.

Development and design-verification tests of attenuators will commence. They will be conducted in a vertical drop tower.

Laboratory investigation to establish an operating range for CHEM-MILL processing of L-605 alloy will begin.

The launch-escape system structure design will be released.

Detailed drawing for the Apollo test requirements test program will be released.

SERVICE PROPULSION SUBSYSTEM

PRESSURIZATION SYSTEM

Design layouts using a schematic for a service propulsion subsystem (SPS) employing two normally closed squib valves with a series-parallel regulator are in progress. This system is illustrated in Figure 7. In an effort to achieve optimum design, S&ID is studying other pressurization system concepts.

PROPELLANT TANK AND DISTRIBUTION SYSTEM

Continued development of the SPS configuration consists of a dual-oxidizer, dual-fuel tank arrangement that results in isolation of this system from the service module reaction control system (RCS). This isolation is believed advantageous because it results in a simpler, lighter system. Furthermore, the respective engines will not be interdependent in regard to inlet pressure.

Figure 7 illustrates the incorporation of expulsion devices in the SPS tanks.

In this concept, another advantage is positive expulsion devices are required in the RCS engines (Figure 8). In the RCS, the devices assure firing of the attitude control rocket engines.

Another concept employs the service module RCS rocket engines to supply sufficient acceleration to settle the propellants in the SPS tanks, enabling the service propulsion engine to fire.

Two types of positive expulsion devices and a simulated fuel tank are being fabricated so that the concept may be evaluated. One device is a mechanical bellows; the other is an umbrella spring-loaded bladder.

PROPELLANT SYSTEM SERVICING

The preliminary layout of SPS and RCS fill and vent connections has been prepared. Studies under way concern personnel safety, GSE, servicing time in relation to countdown, servicing time in relation to equipment (GSE and airborne lines and connectors), structural accommodations, and space allocation on the spacecraft.

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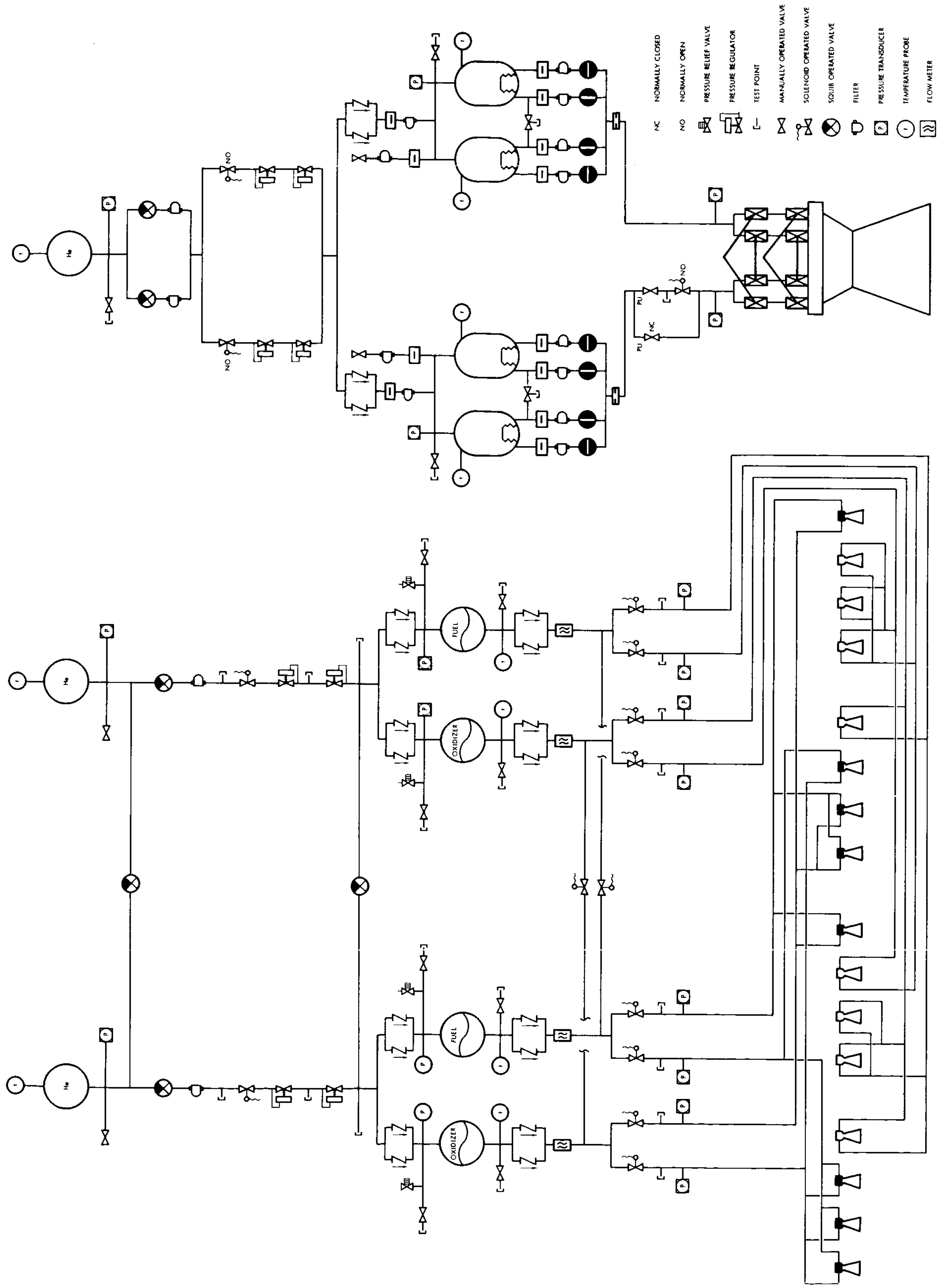

Figure 7. Positive Expulsion in the Service Propulsion Subsystem, no Interconnection to Reaction Control Subsystem

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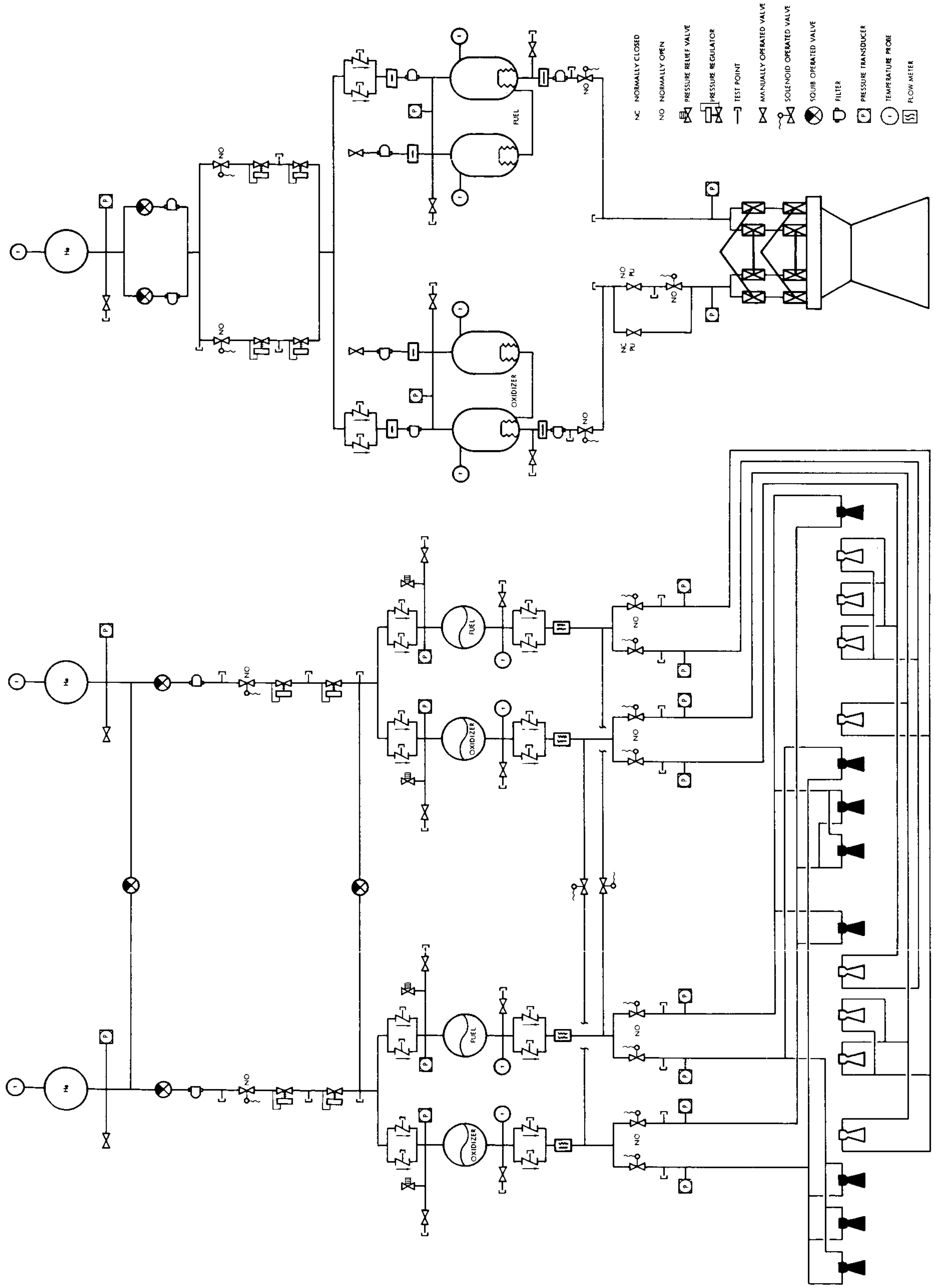

Figure 8. Propellant Setting by Reaction Control Subsystem Thrust

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ROCKET ENGINE

Performance

Aerojet-General was selected to supply the SPS rocket engine. A preliminary procurement specification was issued.

The SPS rocket engine operates with a pressurized propellant feed system and utilizes ablative materials to provide combustion chamber cooling. Performance requirements are as follows:

Item	Requirement
Thrust	21,500 lb
Specific impulse	315 sec (minimum)
Mixture ratio	2.0:1
Propellant inlet press	150 psia
Nozzle expansion ratio	40:1
Cutoff impulse accuracy	±150 lb per sec

Design

Preliminary study results indicate that spacecraft weight may be significantly reduced by using a nozzle with an area ratio of approximately 60:1. However, since weight reduction is a function of the clearance dimension between the nozzle exit and the adapter-booster interface, the final design selection nozzle area ratio awaits determination of the clearance dimension to be used.

Three types of gimbal system actuators are under study.

TESTS

Preliminary test plans for the SPS have been completed.

Work has begun on the program to establish physical and functional requirements of the tanks used in the preliminary flight rating test program.

[redacted]

FACILITIES

S&ID and Aerojet-General personnel met to discuss the overall engine test stand envelope.

Design layout effort has been directed toward the establishment of the overall test stand envelope. Spacecraft propellant system layouts are being modified to accommodate off-the-shelf components closely simulating prototype equipment.

STUDIES

A plan of action has been prepared for evaluation of the parameters involved in obtaining joint seals for plumbing connections and component installation methods for the SPS. The feasibility of using plastic tankage and plumbing is being studied.

PLANNED ACTIVITIES

Completion of test procedures for the positive expulsion devices.

Initiation of a program to test sealants for plumbing connections.

Continuous study of propellant system servicing.

Modification of spacecraft propellant system layouts in conjunction with a survey and selection of suppliers capable of furnishing off-the-shelf components.

Coordination with the engine to establish test facility and mobility requirements for the test stand.

Completion of the rocket engine procurement specification.

Determination of the rocket engine nozzle-expansion exit area ratio.

Comparative study to determine the optimum gimbal actuator system.

Initiation of the expulsion device test plan.

SERVICE MODULE STRUCTURE AND SUBSYSTEM INSTALLATION

WEIGHT ANALYSIS

Propellant Usage

Lunar launch center-of-gravity travel about all three axes was determined for 13 schemes of service module propellant usage. These data will assist in the selection of a propellant system and the sequence of propellant usage.

Fuel Cell Storage Tanks

An increase of 57 lb in weight allowance for the supercritical storage tanks, which will contain fuel cell reactants, was necessitated by two design changes. Tank diameter was increased by 0.5 in. and aluminum, rather than titanium, was used as the material for the oxygen and hydrogen containers for compatibility.

Radiators

Seventy pounds overall weight would be saved by using horizontal rather than vertical radiators. The horizontal arrangement is 50 lb heavier than the vertical; but vertical radiators require a heat pump and additional reactants that add 120 lb.

Web Configurations

A trade-off study of an integrally stiffened, semitension field web (shear resistant to limit load) compared with a sheet-metal-stiffened tension field web showed the latter to 8 percent lighter. This comparison did not include fastener weight and secondary cap bending requirements, which would tend to reduce the weight difference between the two configurations. In another study, no appreciable unit weight difference was detected when an integral transverse-stiffened web was compared with a integral waffle-stiffened web.

STRUCTURAL ANALYSIS

Structural analysis achievements and efforts are reflected in Table 10.

Table 9. Structural Analysis Effort April 1962

Component	Configuration Material Procedure	Purpose
Cylindrical shell panel		Sizing structural test articles
Radial shear web	Aluminum-honeycomb-sandwich, waffle-stiffened skin	Sizing structural test articles
Lower bulkhead	Aluminum-honeycomb-sandwich, steel-honeycomb sandwich	Sizing structural test articles
Forward bulkhead	Stiffened skin	To define loads from C/M support fittings and S/M internal equipment
Command-to-service-module fitting	Aluminum forgings and linkage configuration	To determine structural efficiency
Center ring	Aluminum I-section	To determine internal loads
Outer shell	Various core configurations and panel support arrangement of welded-aluminum corrugated web sandwich	To compare with bonded-aluminum honeycomb sandwich (All determined to be heavier.)
Door configuration	Configuration composed of a combination of structural and nonstructural panels	To determine and compare requirements and weights with configurations that are either all structural or all nonstructural
Thrust pad and tension tie loads	Calculated by an iterative process	Calculated minimum compressive pad loads for maximum q and end boost stage I
Body bending stiffness	Distributions	To provide structural data for dynamics analysis of prototype service module
Torsional stiffness	Distributions	To provide structural data for dynamics analysis of prototype service module
Propulsion tank pressurization	Reliability, past experience, existing criteria requirements	To determine whether or not pressure vessel safety factor of Z can be reduced

A laboratory program to develop, test, and evaluate candidate temperature control coatings for use on the Apollo space radiators has been initiated. From a cursory literature search, the polyurethane base elastomers have been found to be the most resistant to high-energy radiation. Adhesive bonding studies for the service module, particularly in regard to the radiators, have been implemented.

STRUCTURAL DESIGN

Primary

A design layout is being made to determine the engine location shift required for attitude control and the subsequent increase in adapter length that results from the center-of-gravity shift as fuel is consumed. The layout depicts various fuel-tank and utilization-sequence systems.

Design studies eliminated a major load-junction transfer penalty by one fitting that combines two tapered beam caps and the command module support fitting. These studies are also investigating the use of the numerical control method of manufacture. Other design studies are continuing on

1. The tension-shear tie system (to determine overall effect on the service module structrual configuration)

2. The aft honeycomb bulkhead

3. The fairing area. Aerodynamic effects of the off-center command module condition are being determined. The fairing may be required to smooth the service-to-command module junction. The present concept calls for all of the fairing to be removable except the area that supports the ground-disconnect umbilicals.

Tanks

Design layouts have been made of the main propellant oxidizer and fuel tanks and the helium main-propellant and pressure tank.

The material selected is 6Al-4V titanium alloy, which will be welded by tungsten inert gas in a metal chamber.

Environmental Control and Electric Systems

Deployment of environmental control system (ECS) radiators, rolling up horizontally at the 1/3 point, is acceptable to present area requirements.

A study of mounting the fuel cells on a platform was made. A removable floor will be provided to facilitate sliding cells in and out of the equipment bay without affecting the antenna deployment linkage.

ANTENNA AND RADIATOR DEPLOYMENT

The following requirements for the antenna and radiator deployment systems have been established:

1. The deep space instrument facility (DSIF) antennas will deploy 8000 miles from earth and will remain deployed at all times
2. Radiators will deploy after lunar landing and will remain deployed until just prior to lunar take-off

Basic studies are being made for antenna deployment, and investigation is continuing on the evolution of a system for radiator deployment.

SEPARATION SYSTEMS

The configuration selected for the command-to-service module separation system incorporates the umbilical plug and load-carrying stud in one large hook fitting that is pivoted at the outer rim of the service module interface. It is held in locked position by a toggle-operated latch on the service module. This is rigged safe by a cable system to an explosive-actuated chopper. A second, larger toggle linked between the service module and the hook fitting is held in folded condition by a gas-operated actuator attached to the center pin joint.

A system was evolved and layouts were made for the service module-to-adapter interface.

REACTION CONTROL ENGINES

Guidance and control considerations indicated a requirement for a dual-thrust-level reaction control system. This system requires twelve 5-lb engines and sixteen 100-lb engines.

Studies to determine locations for both levels of engines are under way. The study of the 100-lb engines considers an extendable placement, as well as a fixed one. Heat transfer data are being obtained so that the optimum radial location of engine thrust centerline can be determined.

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MOCK-UP

A new mock-up schedule was issued, and the design for it was frozen. Freeze dates, especially for mock-up 4 and 7, were established to allow sufficient manufacturing time before the preliminary NASA inspection scheduled for 15 June 1962.

Specific mock-up status is shown in Table 10.

BOILERPLATES

Design of the service module and adapter as one unit (for simplicity and cost saving) was explored, but not adopted. When designing boilerplates 9, 13, and 15 in this manner, S&ID discovered fabrication and handling disadvantages that outweighed design cost saving. Separate design continues as planned.

Detail drawings on the lower frame assembly, skin assembly, vertical panel assembly, and angles of boilerplates 9, 13, and 15 are complete. At the request of NASA, an access door has been incorporated into these boilerplates.

PLANNED ACTIVITIES

S&ID is preparing a proposal, which will be submitted to NASA, for a two-stage service module and lunar landing module. Structural requirements are being studied, and a technical write-up is being prepared.

Basic layouts of major components will continue. Structural test drawings to be released include the radial beam, aft bulkhead, and heat shield shell panel.

Further work will seek to define locations for the components of the dual-level reaction control system. The 20k engine will be located at the proper gimbal angle for the required center-of-gravity shift.

Layouts will be released for the main propellant oxidizer and fuel tanks and the helium main propellant and pressure tank.

Preliminary laboratory studies will proceed on the development of the minimum data necessary to determine whether more extensive consideration should be given to use of plastic tanks.

The manufacturing completion schedule was published, and detail fabrication of the service module was scheduled to begin.

Table 10. Mock-up Status, Service Module

Number	Nomenclature	Configuration	Status
4	Service module and adapter interface	Lower section of service module and upper section of adapter	Structural fabrication started. Separation mechanism under design. Mating fixture being completed.
7	Complete service module	Semihard of complete service module	Fabrication started.
9	Spacecraft handling and transportation	Hard-launch escape module, command module, service module, and adapter	Service module, command module, and adapter being fabricated of steel. Fabrication will simulate actual weight without excessive ballast.

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ELECTRICAL POWER SUBSYSTEM

ELECTRICAL SYSTEMS DESIGN

A preliminary, functional sequential diagram has been developed for SA-9 and SA-10. The initial sequencers will utilize relays. The relative merits of relays are being compared with solid-state devices for use in the sequencer.

A preliminary functional list of pyrotechnic operations has been developed. The study of the advantages and disadvantages of hot-wire squib versus exploding bridge wire pyrotechnic initiation is in progress.

Minimum leakage requirements in the NASA work statement will require the use of metallurgical sealing for all command module pressure-barrier penetrations. Fusion techniques will be used for sealed electrical umbilicals and feed-through connectors. Since stainless steel shells with fused glass inserts can be fused to the aluminum structure, S&ID is currently investigating several techniques for fusing these materials.

Studies and preliminary designs are being conducted to determine requirements for interstage and intermodule bonding (grounding). Applicability of MSFC-STD-110 to the Apollo vehicle indicate that suggested bonding approaches will not impose an excess design penalty upon the Apollo spacecraft.

ELECTRICAL POWER DISTRIBUTION SYSTEM

The load analysis and system characteristics are shown in Table 11.

Table 11. Load Analysis System Characteristics

Mission	Power (w)			Energy
	Peak	Average	Minimum	(kwh)
14-day lunar landing	2815	1540	1235	518
7-1/2-day lunar landing	2815	1760	1235	306
8-1/2-day lunar orbit	2675	1830	1560	373

[redacted]

CO[redacted]

A re-evaluation of the load requirements and duty cycles of the post-landing phase has resulted in a reduction of battery capacity from 2350 to 1250wh. The entry battery, though designed for a 1/2-hr discharge rate, should provide sufficient energy during the post landing phase at a seven-day discharge rate. Therefore, necessity of developing two types of batteries no longer exist; the three spacecraft batteries should be identical.

SYSTEM POWER REQUIREMENTS

The power requirements for vehicle systems, except for the guidance system, will be three-phase 400 cps.

The isolated dc power and dc voltages other than 28 v should be produced from the three phase, 400-cycle bus by the use of transformer rectifiers within the system. This method of providing ac and special dc power results in an overall weight savings, less radio interference generation, fewer components, less development effort, and greater reliability.

Studies have indicated the desirability of correcting the inverter output power factor to approach unity. The added filter weight (one for each of three inverters) is less than the added fuel cell reactants required, because of the lower inverter efficiency at power factors less than unity. The inverter rating will now be on the order of 1200 w at 400 cps, three-phase 115/200 vac.

INTERIOR LIGHTING AND FUEL CELLS

Laboratory testing to determine the qualifications of the fluorescent floodlight components was intitated.

S&ID deleted from its original specification the requirement for in-mission, re-start capabilities; reverse current switching; and the black anodizing of the module exterior.

Schematics of redundant and single manifold reactant feed systems were analyzed for reliability. A single manifold is a more reliable system. Service module design studies of the shock-mount allowance for the fuel cell has definitely proven a need for this type of mounting.

FACILITY REQUIREMENTS

Instrumentation, equipment, and facility requirements have been the areas of special effort during this reporting period. Comprehensive review of facilities and equipment requirements were conducted. Procurement specifications were initiated for equipment.

PLANNED ACTIVITIES

Configurations of pyrotechnic and sequential systems for boilerplate 6 will be defined. Preliminary configurations will be requested for SA-8, 9, and 10.

REACTION CONTROL

SPECIFICATIONS

Specifications for the helium and propellant positive expulsion tanks are being completed. Performance specifications for the reaction control system (RCS) of the service module and the command module were completed.

PRESSURIZATION SYSTEM

Current studies include replacement of dual helium tanks with a common tank. This configuration, shown schematically in Figure 9, presents fewer potential leak points and weighs less than the dual helium tank configuration. The concept presents no degradation in reliability.

Series check valves, which have replaced series-parallel check valves, are considered adequate because the propellant tankage is a dual system and the redundant propellant is still available if a check valve fails closed.

ROCKET ENGINE

Performance

Procurement specifications defining design and performance levels of the reaction control engines have been prepared. The guaranteed engine performance levels are summarized in the following listing:

Item	Measurement
Vacuum thrust	100±5 lb
Specific impulse	
Steady state	300 sec
10 ms pulse	250 sec

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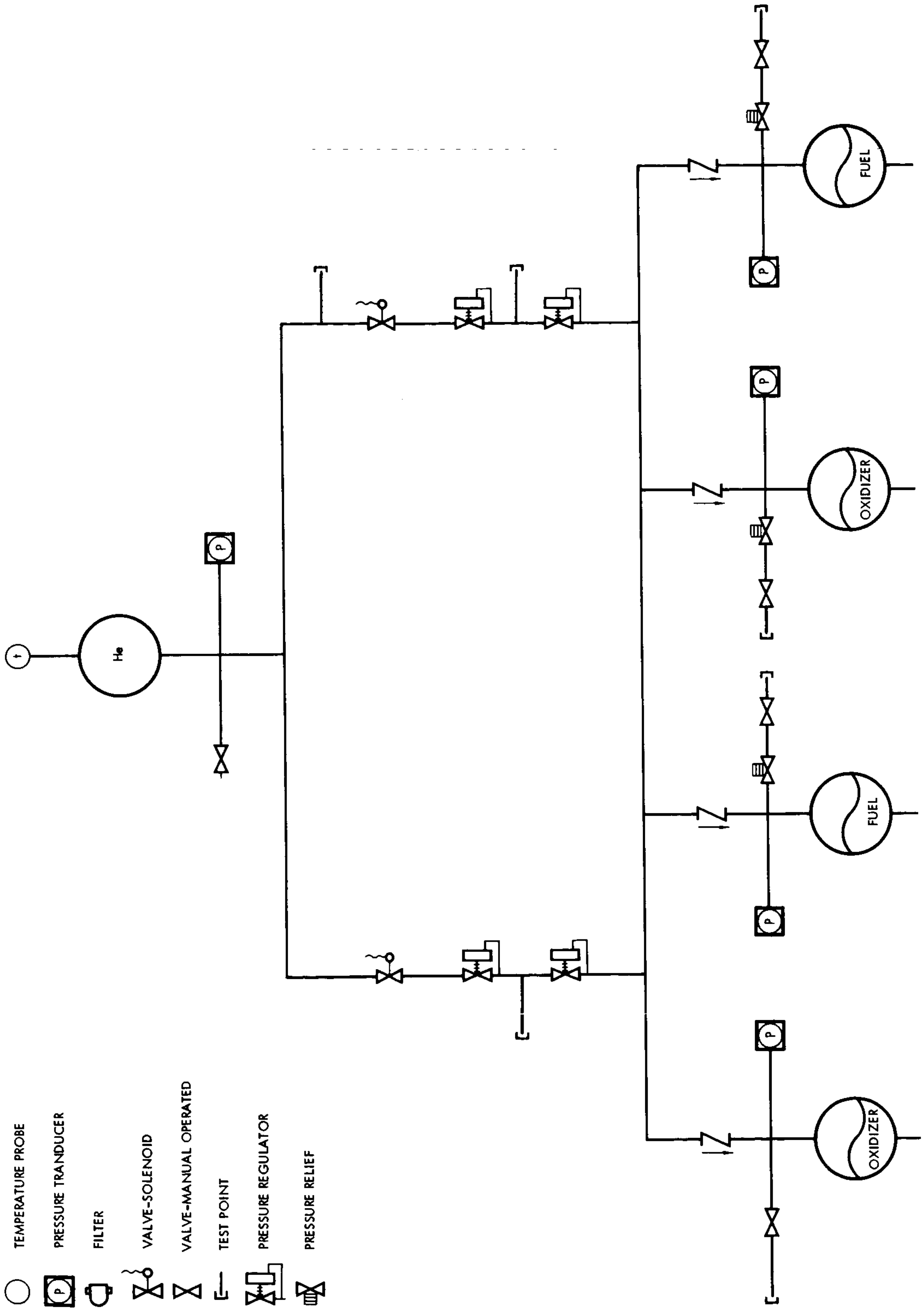

Figure 9. Pressurization System Utilizing Common Tank

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Item	Measurement
Minimum impulse	1 lb sec maximum
Reliable operating life	
Command module	200 sec
Service module	1000 sec
Total operating life	
Command module	600 sec
Service module	1800 sec

Design

Thermodynamic analyses of the re-entry environment in the vicinity of the command module reaction control thrust chambers indicate an overheating condition for engines radially located 85 deg or closer to the stagnation point. The engines closest to the stagnation point would be subjected to heat fluxes which would endanger the structural integrity.

Efforts to relocate the engines further from the stagnation point resulted in a configuration that still retains the capability to provide adequate command module attitude control. The new locations are depicted in Figure 10.

A present study considers two approaches to determine cooling provisions for the command module reaction control engines. The other approach provides a cooling jacket around the expansion nozzle.

Design layouts defining the command module reaction control engine locations, engine-to-structure interface connections, and mounting provisions were drafted.

Mock-up drawings defining the current engine configurations and equipment locations have been released. Boilerplate drawings are in progress.

STUDIES

Marquardt is investigating protective coatings and/or high-temperature materials capable of withstanding the re-entry environment. Preliminary studies on propellant handling, compatibility flushing, and cleaning procedures are progressing.

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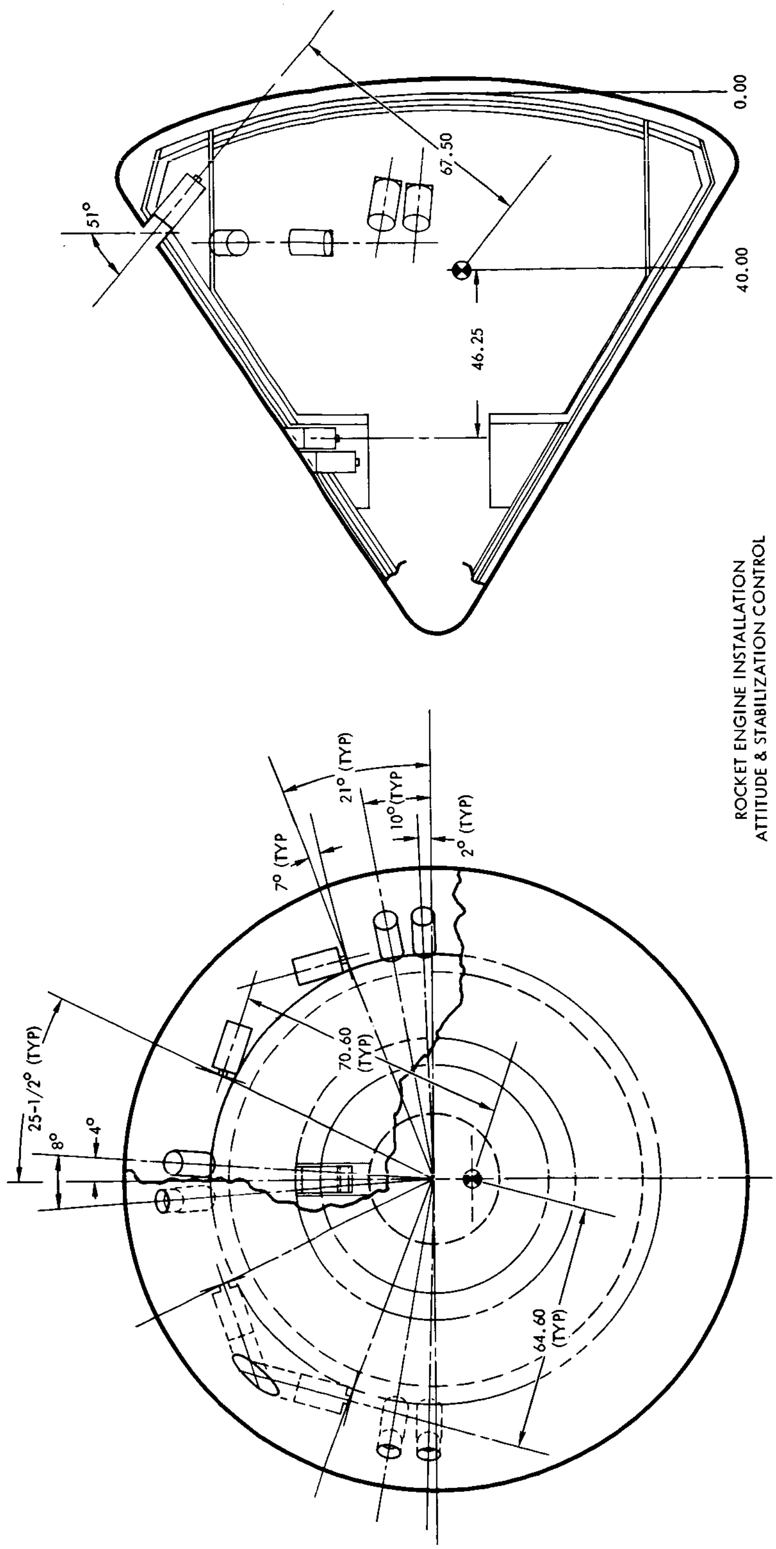

Figure 10. Attitude Control Engine Location

Investigations are in process for a nontoxic, nonflammable fluid that has approximately the same density and viscosity as the hypergolic propellants to be used for systems testing. In addition, feasibility studies are being made to determine methods to clean and to decontaminate the test systems for tests using propellants composed of nitrous tetroxide as oxidizer and hydrazine and unsymmetrical dimethylhydrazene as fuel.

TESTING

Detailed test plans for the breadboard testing of the command module and service module RCS were incorporated into the revised Apollo Test Plan (SID 62-109).

Fabrication of the command module breadboard test stand continues on schedule. The test stand frame is 75 percent complete. The reaction control equipment compartment is 10 percent complete. Preliminary test procedures for component evaluation tests have been completed.

PLANNED ACTIVITIES

The release of procurement specifications for airborne hardware will start during the next report period.

Fabrication of the command module breadboard will continue. Procurement of hardware for the breadboard will be initiated, and vendor selections will be established.

The letter contract with Marquardt will be signed. Marquardt will begin a developmental test program to substantiate their design.

S&ID will initiate study of the scarfed nozzle extension of the command module.

Boilerplate layouts for the RCS of both modules will be completed.

SPACECRAFT ADAPTER DESIGN, FABRICATION, AND ASSEMBLY

STRUCTURAL REQUIREMENTS

Weight analysis determined that an adapter designed for the C-1 configuration would weigh 95 lb less than an adapter designed for C-5 configuration. This difference results from the lower booster loads of the C-1 vehicle.

Detailed drawings of bonded aluminum honeycomb panels for structural testing are being prepared. One panel includes a blow-out door. These panels are typical of the honeycomb design for the adapter skin panels. The aft attach ring (lower end interface) is being redesigned. The redesigned ring should be much lighter than the ring shown on Marshall Space Flight Center drawings. An adapter cylindrical shell panel is being sized for existing structural requirements, and the torsional stiffness of the adapter is being determined.

STRUCTURAL DESIGN

Individual adapter designs were selected for the C-1 and C-5 vehicle configurations because of the differences in booster loads. Because design loads for the C-5 are almost three times as much as design load for the C-1, an intolerable weight penalty would result if the adapter configuration for the C-5 were used for the C-1.

Figure 11 depicts the configuration selected for the C-1 vehicle. This configuration incorporates one access door and three blowout panels.

MANUFACTURING

The manufacturing completion schedule for the spacecraft adapter was completed during the report period.

SEPARATION SYSTEM

Two systems are being evaluated for the system that separates the service module from the adapter. The first is a cable actuated mechanism; the second is an explosive bolt release device.

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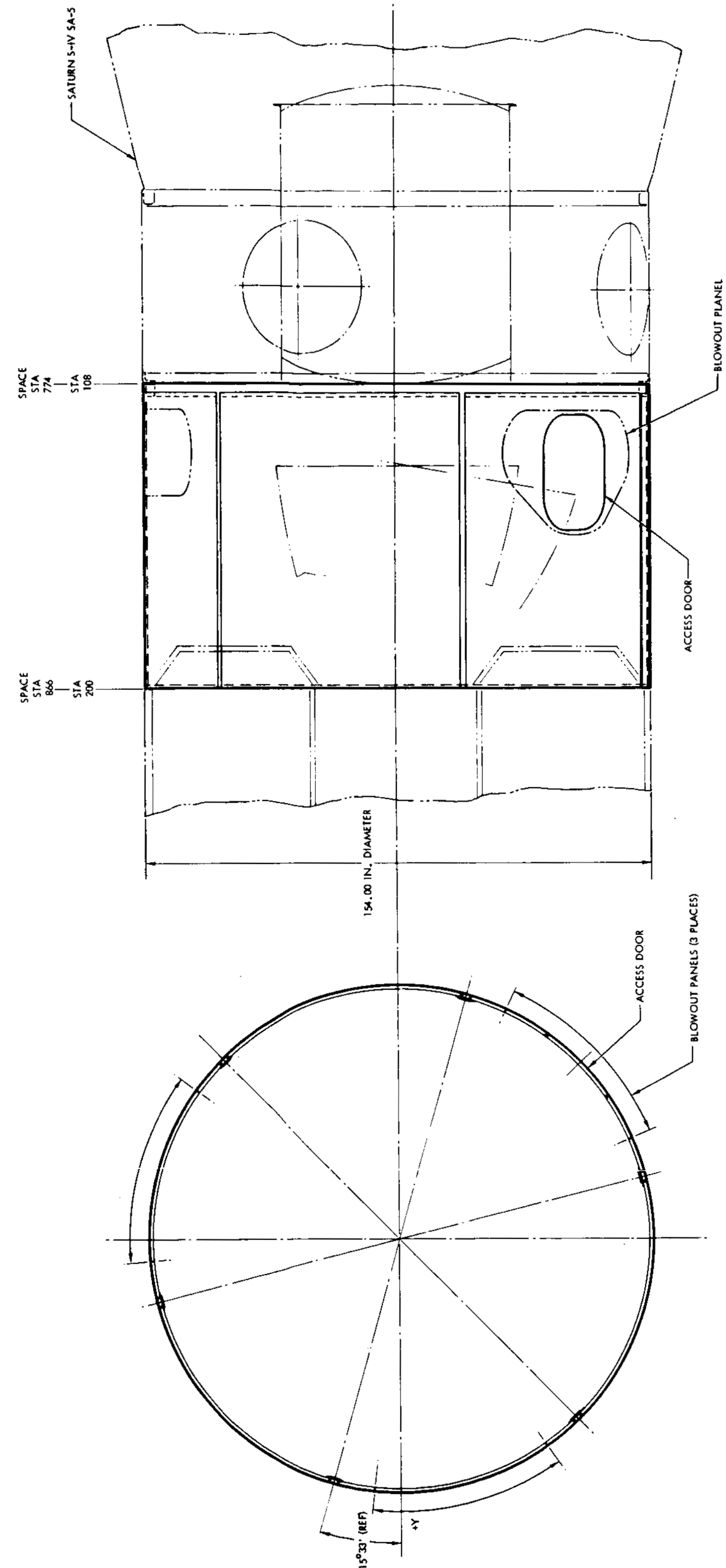

Figure 11. Adapter Configuration for C-1

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MOCK-UP

Fabrication of mock-ups 4 and 6 has begun. These mock-ups have been fabricated for the purpose of the service module-adapter interface.

PLANNED ACTIVITIES

Completion of the basic layout of the adapter for the C-1 configuration.

Issuance of production drawings of panels, longerons, fittings, and attach fittings.

Definition of the optimum release device for the separation system.

Sizing of the components of the C-1 configuration.

Beginning of the detail fabrication of the adapter.

SPACECRAFT GROUND SUPPORT EQUIPMENT

SYSTEM REQUIREMENTS

A major effort directed toward developing the checkout concept included a study of checkout requirements and conditions under which they will occur, methods of connecting the GSE and spacecraft systems, and methods of implementing the checkout. Requirements for the checkout computer were investigated, and a preliminary evaluation of available equipment was initiated. An analysis of the general and specific requirements for control room system checkout groups was also initiated. Preparation of a briefing to describe the checkout console was completed.

A general approach to the computer programing for Apollo checkout has been studied, and a plan that will permit maximum use of the computer and facilitate instruction changes has been formulated.

COMMAND MODULE GSE

April progress was marked by the release of six handling-type GSE items to support boilerplate 1. Planning and scheduling documents have been published on these items, and fabrication effort is expected to parallel engineering information in May.

DESIGN

Design of handling the GSE for boilerplate 1 was completed. The preliminary designs of the telemetry, launch control, and maintenance trailers for the boilerplate program were also completed. The procurement specification for this equipment is being prepared.

Facilities criteria for the propulsion development test facility and the Apollo spacecraft modification and checkout center were developed during this reporting period. Preliminary information was discussed with NASA.

PACKAGING AND TRANSPORT

A comparison of several aircraft (fixed and rotary wing) relative to their use as carriers for command module air-drop tests has been made. To meet the test criteria established by the Apollo mechanical systems group, an air-drop vehicle must be capable of achieving a minimum altitude of 20,000 ft. S&ID based their choice of the C-133A on the aforementioned comparison.

The report on the packaging criteria and performance requirements for program Apollo airborne equipment, General Requirements for Preparation for Delivery of Apollo Airborne Equipment, S&ID 62-240, has been completed. Preliminary packaging plans and packaging data sheets for all boilerplates have been completed.

PLANNED ACTIVITIES

Criteria for the test facilities required for boilerplates and prototype spacecraft will be developed. A detailed analysis and systems engineering for checkout, tests, and data-handling subsystems will be started. The initial design of all GSE categories for boilerplates and prototype spacecraft will be started. Preparation of individual GSE procurement specifications will be initiated.

GROUND OPERATIONAL SUPPORT SYSTEM

REQUIREMENTS

Various types of displays and indicators were studied. Special attention was devoted to analyzing requirements for indicators and malfunction displays.

INFORMATION FLOW

The functions of the GOSS network by mission phase (particularly for the lunar landing mission) are being studied. This breakdown serves as a guide for determination of types of information flow necessary for the effective performance of the GOSS mission.

PLANNED ACTIVITIES

The mission-phase approach will be pursued to accomplish a functional analysis of the GOSS network. Display and indicator studies will continue. The GOSS system performance and interface specification (SID 62-76) effort will continue.

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FACILITIES

PROGRAM MANAGEMENT AND ENGINEERING AREAS

Program management, engineering, and other Apollo functional division areas have been expanded from 45,000 sq ft to 95,000 sq ft.

MANUFACTURING AREAS

Layouts have been completed for the bonding and test facility, systems integration and checkout facility, and plaster master facility. A preliminary layout of the boilerplate assembly facility was completed.

ENGINEERING SUPPORT AREA

S&ID will design and build a command module impact attenuation test facility at Downey. The facility will consist of a 125-ft structure for support of a 91-ft pendulum carrying the command module. Preliminary drawings of the basic facility and analysis of facility auxiliary components have been completed, and the instrumentation and photographic requirements have been established. Computer programs are being set up to establish initial requirements to achieve the required impact conditions and to verify compliance with these requirements.

Site location for the space systems development facility has been assigned, and area and equipment requirements are being developed. Additional facilities to support the Apollo program (e.g., reaction control, acoustics, etc.) are being studied.

FACILITIES ENGINEERING

Design criteria for the following facilities have been submitted to NASA:

1. Plaster master
2. Bonding and test
3. Systems integration and checkout
4. Parking
5. Radiographic

6. Building 6 modification

7. Impact test

Design criteria for other Downey facility requirements are being prepared for submittal during May 1962.

PLANNED ACTIVITIES

Facilities Appendix "A" for Downey facility requirements FY 62-63 and the Appendix "A" for the propulsion test facility are scheduled to be submitted in May, 1962.

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APPENDIX

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Table A-1. Meetings, April 1962

Subject	Meeting	Location	Date	S&ID Representative	Organizations
Coordination of all Apollo test facilities	1	Houston, Texas	1 - 3 April	McKim	S&ID, NASA
Discussion of backup guidance mechanization of Apollo	2	Sunnyvale, California	1, 2 April	Timothy	S&ID, Minneapolis-Honeywell
Program schedules, revised program test plan	3	Downey, California	2 April	Paup Sherman Feltz Fleetwood Crossfield Harvey Warden	S&ID, NASA
Electromagnetic interface coordination meeting	4	Houston, Texas	2 April	Ciglar	S&ID, NASA
Maintenance requirements review and coordination	5	Cocoa Beach, Florida	3 April	Pollard	S&ID, NASA
S&ID-MIT coordination meeting	6	Downey, California	3 April	Kennedy	S&ID, MIT
Discussion of operating procedures, PERT interfaces. IDC's handling of navigation and guidance system meeting	7	Cambridge, Massachusetts	4 April	Griffith-Jones Campbell Thomas	S&ID, MIT
Definitions and guidelines: tooling, facilities	8	Houston, Texas	4 April	Toomey	S&ID, NASA
PERT requirements and numbering system	9	Houston, Texas	4 April	Foist Spencer	S&ID, NASA
Apollo wind tunnel test	10	Mountain View, California	8 - 14 April	Crowder	S&ID, Ames Research Center
Program control techniques, including PERT	11	Sunnyvale, California	9 April	Dehart Griffall Smith	S&ID, Minneapolis-Honeywell
American Welding Society Convention: lectures, equipment demonstrations	12	Cleveland, Ohio	10 - 12 April	Olsen	Symposium

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Table A-1. Meetings, April 1962 (Cont)

Subject	Meeting	Location	Date	S&ID Representative	Organization
Mercury program discussion	13	St Louis, Missouri	10 April	Stelzreide	S&ID, McDonnell Aircraft
Presentation at IES meeting	14	Chicago, Illinois	16 April	Stelzreide	Symposium
Technical coordination of SCS	15	Houston, Texas	10 - 13 April	Barmore	S&ID, NASA
Studies of fuel cell radiator coating, effects of space environment	16	Sunnyvale, California	10 - 18 April	Brewer Blanchard	S&ID, Minneapolis-Honeywell
Maintenance and support plans and handbooks planning	17	Downey, California	11, 12 April	Johnson	S&ID, AiResearch, Collins Radio
Quality control coordination	18	Downey, California	11 April	Griffith-Jones	S&ID, NASA
Mechanical Integration Panel meeting	19	Houston, Texas	11 April	Nicholas Mower White	S&ID, NASA
Mechanical Integration Panel meeting	20	Huntsville, Alabama	12, 13 April	Nicholas Mower Donaldson White Walkover Warner	S&ID, NASA
NASA-S&ID coordination for AEDC survey of Tullahoma, Tennessee, facilities for environmental proof spacecraft and propulsion system spacecraft	21	Houston, Texas	11 - 13 April	McKim Sweeney	S&ID, NASA
Fuel cell radiator coating and space environment effects discussion	22	Palo Alto, California	11 April	Barnett Cooke	S&ID, Lockheed
Program control techniques including PERT	23	Sunnyvale, California	11 - 13 April	Dehart Griffall Smith	S&ID, Minneapolis-Honeywell
MIT facility requirements at Downey	24	Downey, California	12 April	Campbell Mundy Piroutek	S&ID, MIT

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Table A-1. Meetings, April 1962 (Cont)

Subject	Meeting	Location	Date	S&ID Representative	Organization
Apollo briefing	25	Houston, Texas Huntsville, Alabama	12 - 17 April	Ryker	S&ID, NASA
Quality control plan and procurement coordination	26	Downey, California	13 April	Griffith-Jones	S&ID, NASA
Coordination of wind tunnel test, Apollo launch configuration	27	Langley AFB, Virginia	15 - 17 April	Schurr	S&ID, NASA
Window design, testing, functions discussion	28	St Louis, Missouri	15, 16 April	Beam	S&ID, McDonnell Aircraft
Stabilization and control/navigation and guidance interface meeting	29	Downey, California	16 April	Campbell	S&ID, NASA, MIT
Apollo antenna procurement discussion	30	Houston, Texas	16 April	Pope Page	S&ID, NASA
Preliminary pre-test conference: heat transfer tests 0.045 scale model (H-2)—unitary wind tunnel	31	Langley AFB, Virginia	16, 17 April	Biss Allen	S&ID, NASA
Apollo analysis and studies	32	Sunnyvale, California	16 - 19 April	Lu	S&ID, Minneapolis-Honeywell
Technical coordination of SCS	33	Sunnyvale, California	16 - 18 April	Morris	S&ID, Minneapolis-Honeywell
Jet effects testing	34	Langley AFB, Virginia	16 April	McNary	S&ID, NASA
Review of Apollo heat shield statement of work	35	Downey, California	17 April	Kinsler	S&ID, NASA
Apollo facilities coordination	36	Edwards AFB, California	17 April	Parker Esslinger	S&ID
Speech to IAS: "Reliability"	37	Salt Lake City, Utah	17 April	Paup Crossfield	IAS Symposium
Technical coordination and liaison	38	Cambridge, Massachusetts	17 - 27 April	Zeitlin	S&ID, MIT
Data processing re-cycle meeting	39	Houston, Texas	17 April	Reed DeRousha	S&ID, NASA

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Table A-1. Meetings, April 1962 (Cont)

Subject	Meeting	Location	Date	S&ID Representative	Organization
Coordination of quality control facilities at AMR; conference with facilities and material services re facilities requirements and material support procedures	40	AMR	18 - 20 April	Knoles Ford	S&ID, NASA
Briefing on flight safety and mission success	41	Downey, California	18 April	Paup Crossfield	S&ID, NASA
Service propulsion system specification discussion	42	Downey, California	18, 19 April	Warden	S&ID, NASA
Apollo design review	43	Downey, California	19, 20 April	Feltz	S&ID, NASA
NASA coordination meeting	44	Downey, California	19, 20 April	Campbell	S&ID, NASA, MIT
Pre-test conference for Apollo wind tunnel FS-1	45	Mountain View, California	20 April	Allen	S&ID, Ames Research Corp.
Western Psychological Association meeting	46	San Francisco, California	21 April	Hartman	Symposium
Information coordination on data processing techniques re ascent guidance and navigation	47	Minneapolis, Minnesota	22 April	McAllister	S&ID, Minneapolis-Honeywell
Program contract concepts review meeting	48	Downey, California	24 April	Brickman	S&ID, NASA
S&ID-NASA philosophy and approach meeting	49	Downey, California	24 April	Brickman	S&ID, NASA
MIT progress review	50	Cambridge, Massachusetts	24 April	Louie	S&ID, MIT
American Geophysical Union Convention; conference on problems of solar flare phenomena and prediction	51	Washington, D. C. Greenbelt, Maryland Boulder, Colorado	24 - 30 April	Schachter	S&ID, NASA
Engineering coordination	52	Houston, Texas	24, 25 April	Gibb Field	S&ID, NASA

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Table A-1. Meetings, April 1962 (Cont)

Subject	Meeting	Location	Date	S&ID Representative	Organization
Apollo jettison motor design review	53	Elkton, Maryland	24, 25 April	Thies Bellamy	S&ID, Thiokol
Abort conference (suborbital, orbital, midcourse)	54	Cambridge, Massachusetts	25 April	Louie	S&ID, MIT
Midcourse stabilization and radar meeting	55	Cambridge, Massachusetts	25 April	Kennedy	S&ID, MIT
Data facility requirements meeting	56	Houston, Texas	25 April	Britton Rutkowski Speck	S&ID, NASA
Ordnance item installation requirements of launch complex	57	Downey, California	25 April	Pyle	S&ID, NASA
Discussion of ablatives for Apollo heat shield and the testing of materials considered	58	Wilmington, Massachusetts	25 - 29 April	Gershun Nusenow Moen	S&ID, Navco
Design progress meeting: service propulsion system	59	Houston, Texas	25 April		S&ID, NASA, Aerojet General
Trajectory analysis discussion	60	Downey, California	25 April	Ewart	S&ID, NASA
Preliminary structural design mass and dynamics characteristics discussion	61	Downey, California	25 April	Ryker Overton	S&ID, NASA
Meteor protection and structural design discussion	62	Downey, California	26 April	Ryker Overton	S&ID, NASA
Service module, S-IV relationships discussion	63	Santa Monica, California	26 April	Ryker	S&ID, Douglas Aircraft
Training information conference	64	Westchester, California	26 April	Polizzi	S&ID, AiResearch
Apollo abort guidance discussion	65	Cambridge, Massachusetts	26 April	McAllister	S&ID, MIT
Coordination, liaison on navigation and guidance system	66	Cambridge, Massachusetts	26 April - 11 May	Fatton	S&ID, MIT

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Table A-1. Meetings, April 1962 (Cont)

Subject	Meeting	Location	Date	S&ID Representative	Organization
Pressure switch tests/uses conference	67	Downey, California	27 April	Bowden	S&ID, NASA
IAS conference on manned space flight	68	St. Louis, Missouri	27 April - 2 May	Carter	Institute of Aero-Space, Science, Symposium
Presentation: "Reliability"	69	St. Louis, Missouri	29 April	Sivak	Symposium
Contract negotiation	70	Wilmington, Massachusetts	30 April	Kitt	S&ID, AVCO Corporation
Coordination on reciprocal resident representation	71	Minneapolis, Minnesota	30 April	Nelson	S&ID, Minneapolis-Honeywell
Manned Space Flight national meeting	72	St. Louis, Missouri	30 April - 2 May	Peterson	Symposium

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